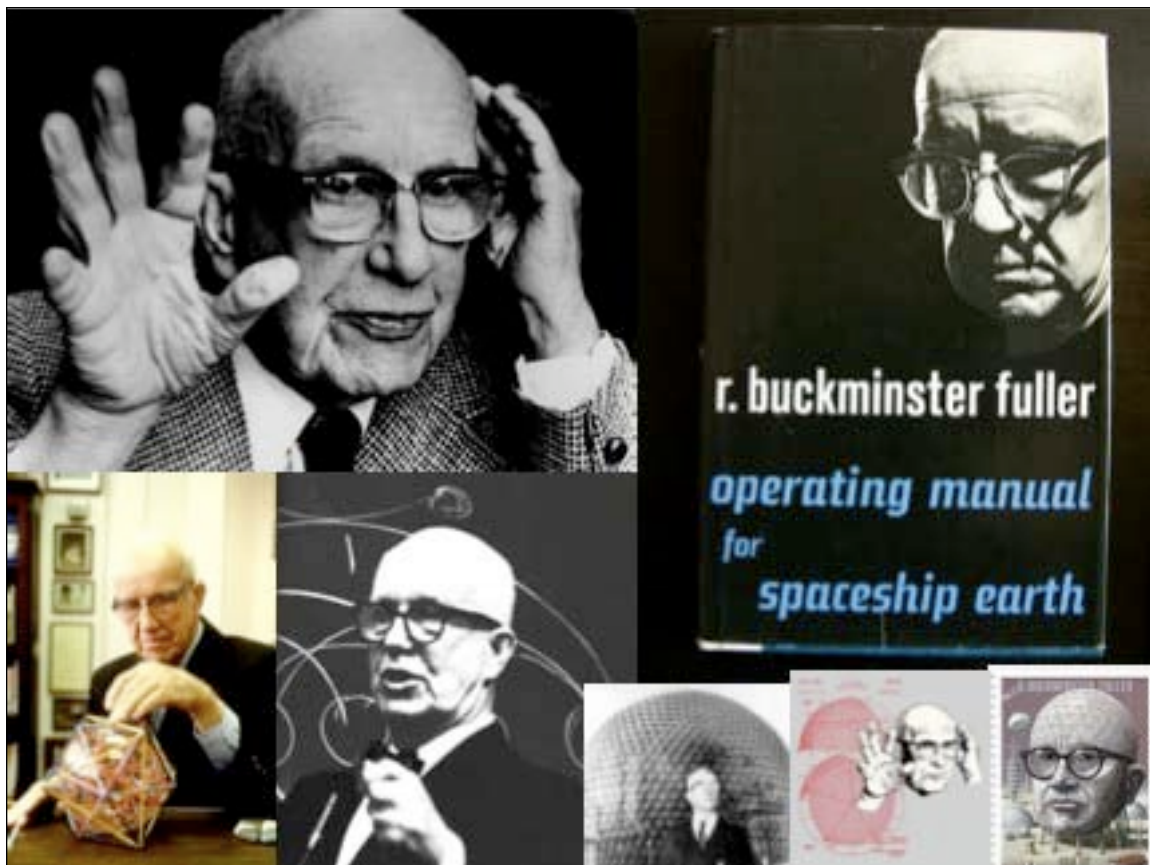
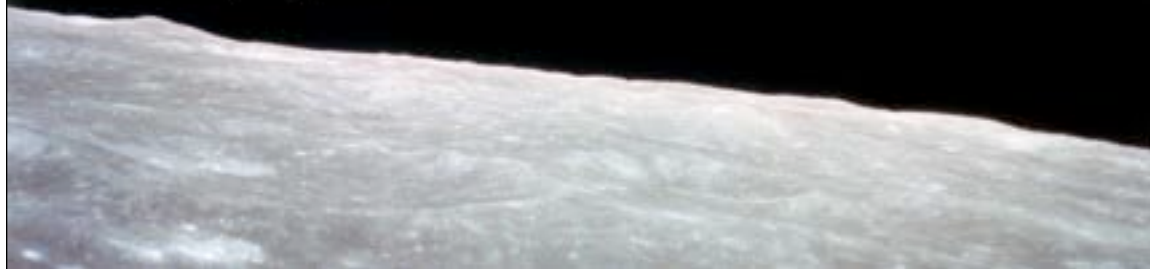


Staying out of Hot Water: Strategic Planning in a Warming World

Evan Mills, Ph.D.
Staff Scientist
U.S. Department of Energy
Lawrence Berkeley National Laboratory



**Loudoun Water Strategic Planning
Future Environment Scan
February 27, 2009**



Our atmosphere is as thin -- in proportion to the Earth's diameter -- as a film of condensation on a steel ball.



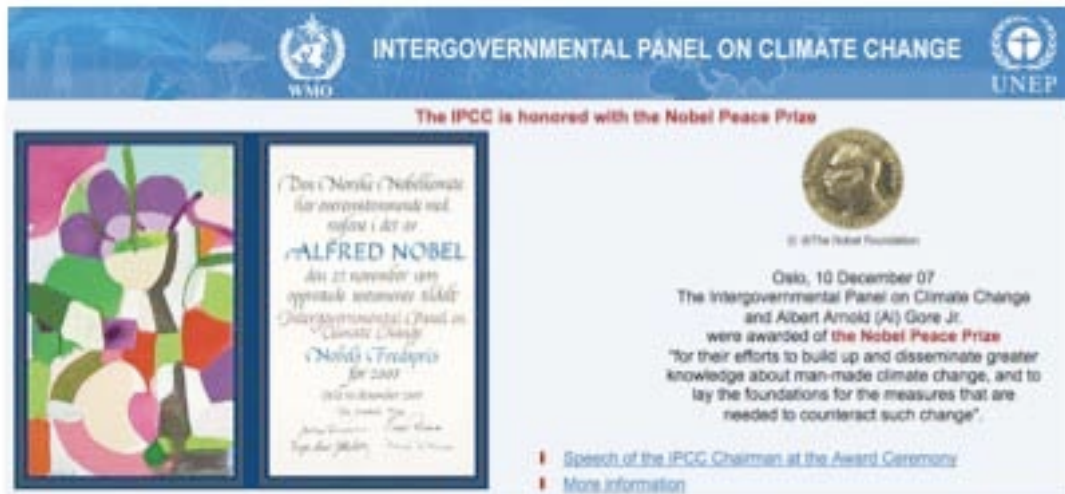
Roadmap

- **State of knowledge on climate**
 - Fingerprints
 - Forecasts
 - Global > National > Regional
- **Relevance for the “water sector”**
 - Supply
 - Demand
 - Energy-Water Nexus
 - Planning
- **What to do?**

US Climate Change Science Program



IPCC



- 25 years in operation
- ~1500 authors from ~200 countries
- Subject to unprecedented peer-review and government oversight (~1000 reviewers)

The Scientific Consensus Nobel Peace Prize: 2007

Intergovernmental Panel on Climate Change

~1500 Authors;
1000 Reviewers

Unanimously adopted by
100+ nations (including U.S.)

IPCC Fourth Assessment Report Co-Recipient of the 2007 NOBEL PEACE PRIZE

<http://www.ipcc.ch>

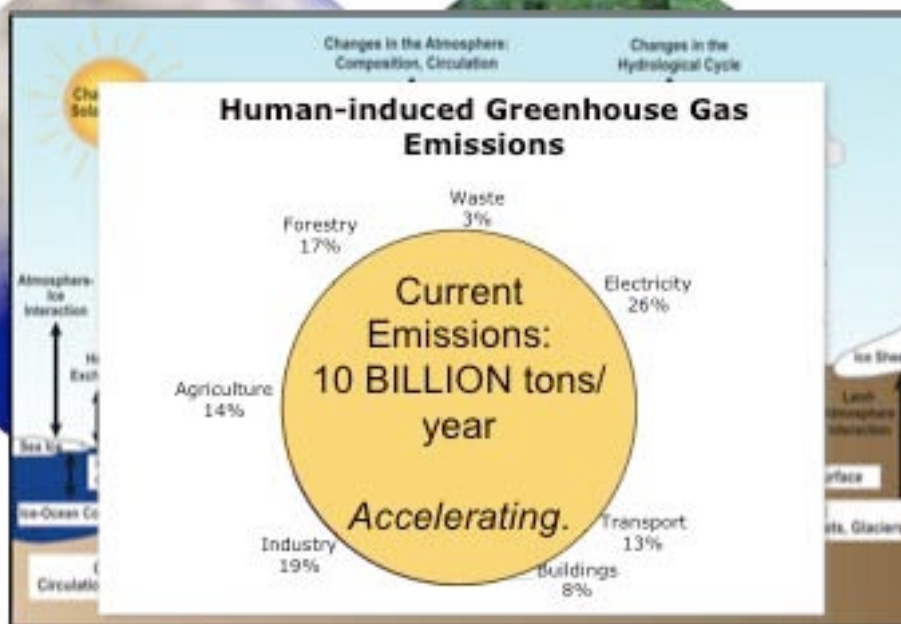
**Warming of the climate system is unequivocal,
with human activity the primary cause.**

- No credible alternative theory
- Impacts observable today
- Change is *accelerating*
- Inaction is *more* costly than action
- Not "too late": Solutions possible (and affordable)
- Must adapt *and* reduce emissions

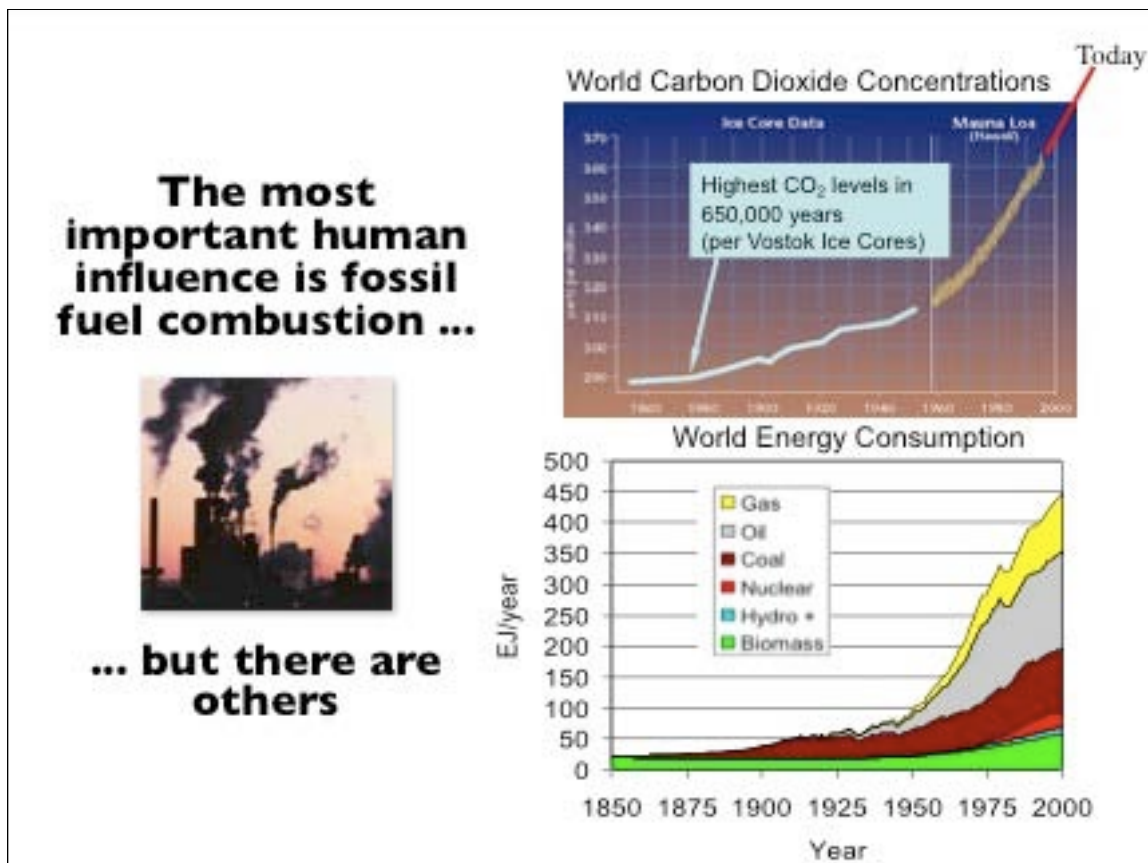
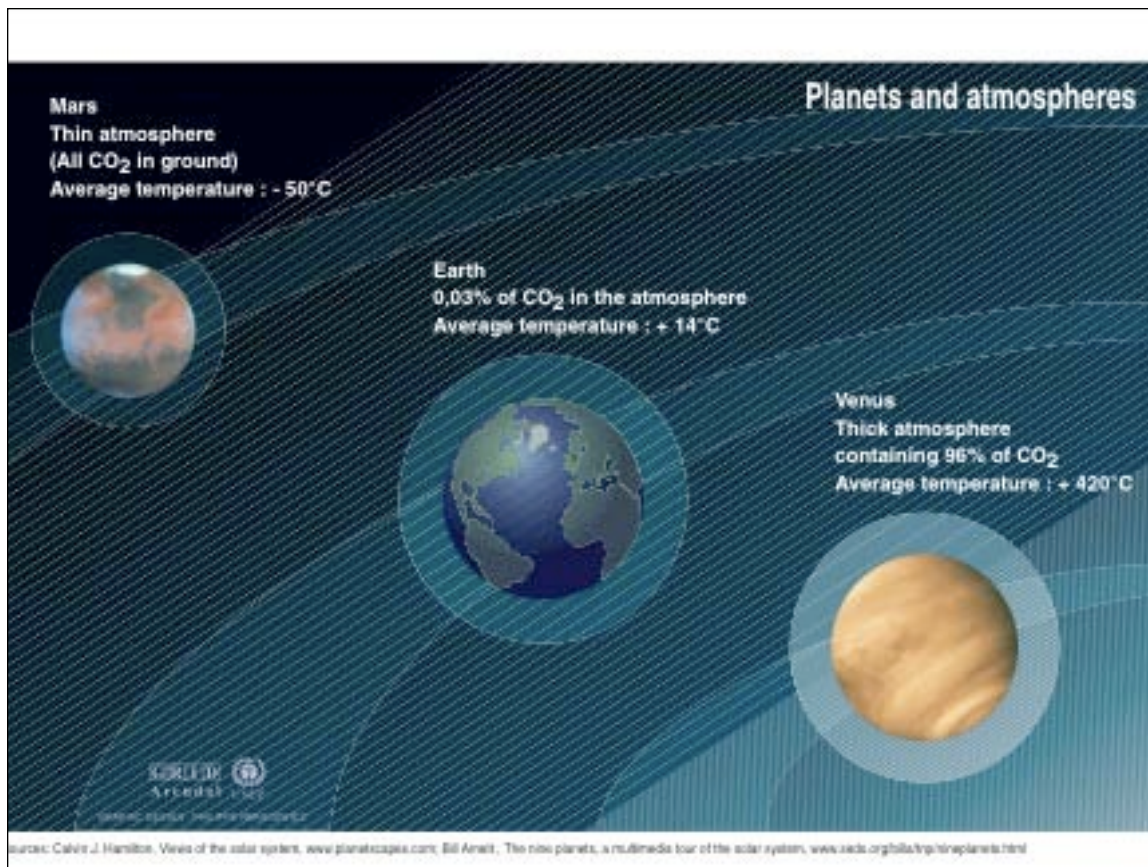
What We've Reluctantly Learned Since the 2007 IPCC Assessment

- Emissions are not declining (they are in fact accelerating)
- Climate responses are emerging *faster* than worst-case scenarios
- Past procrastination will cost us dearly
- It is not a time for complacency

The Climate System



Source: Intergovernmental Panel on Climate Change, Fourth Assessment Report, WGI (2007)



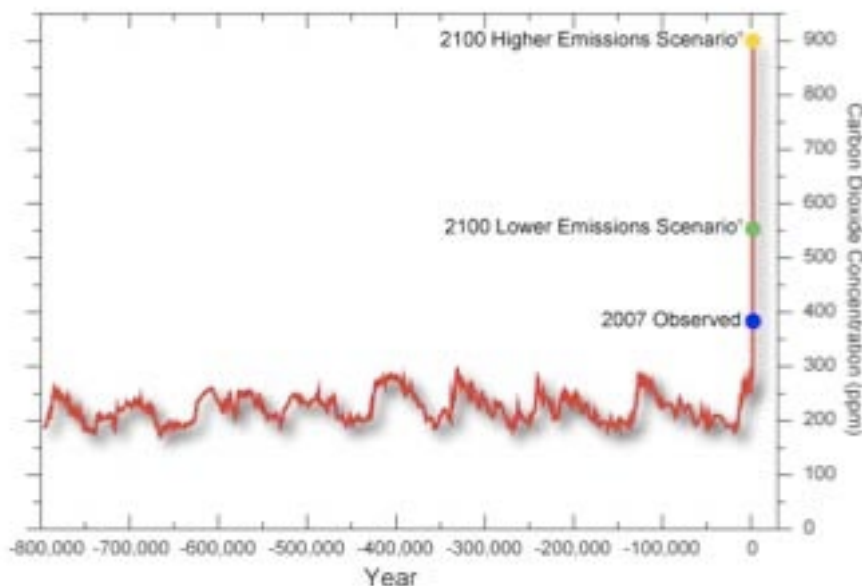
... The second most important human influence is deforestation



Deforestation for soy growing in the state of Mato Grosso, Brazil

Source: Moutinho and Schwartzman, 2005

800,000 Years of CO₂ Concentrations



US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

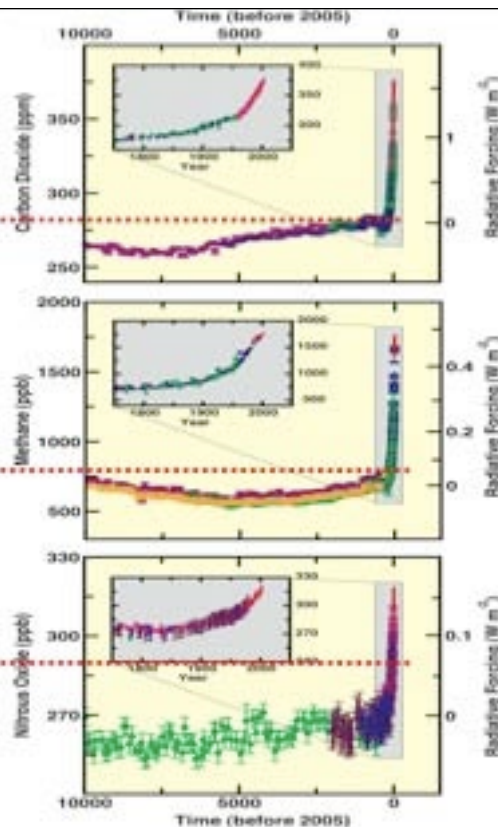
Key Gases

Carbon Dioxide

Peak natural variability over the previous 650,000 years

Methane

Nitrous Oxide



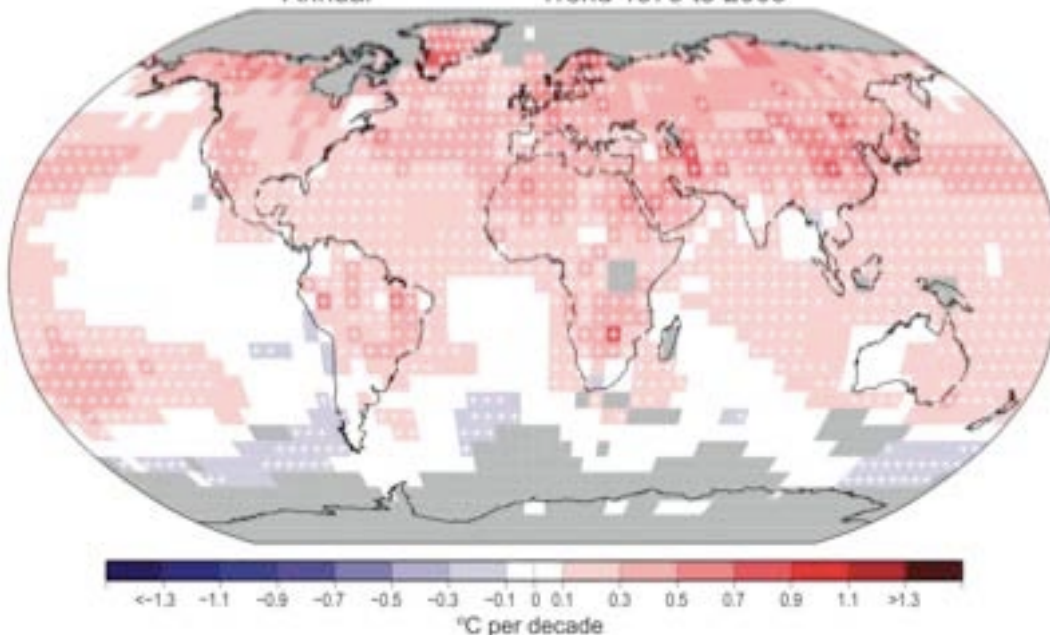
Source: Intergovernmental Panel on Climate Change, Fourth Assessment Report, WGI (2007)

Linear Warming Trend

Areas with a "+" significant at the 5% level

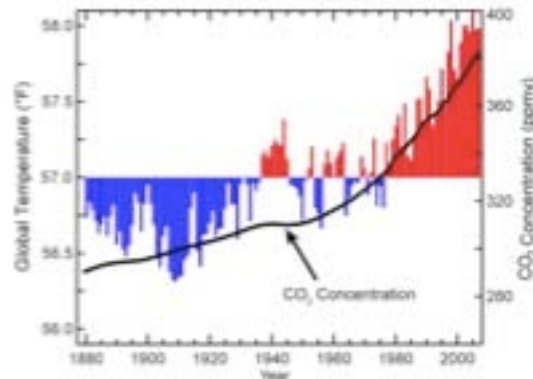
Annual

Trend 1979 to 2005



Source: IPCC: grey indicates insufficient data, 18-years of data used to compute trend.

Global Temperature and CO₂



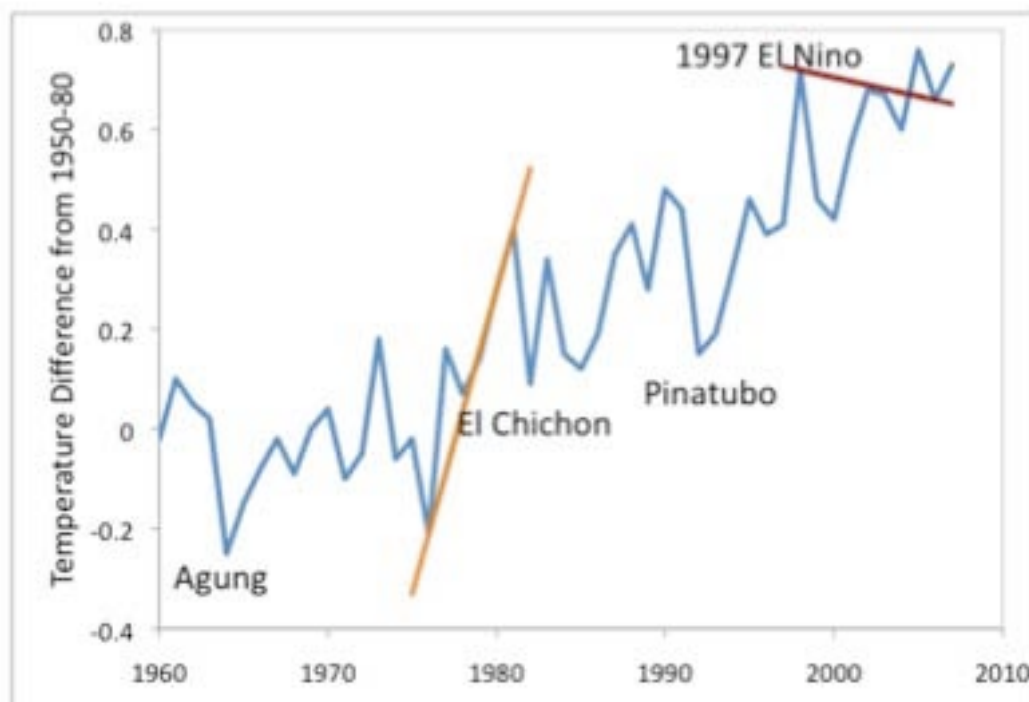
Weather is day-to-day and year-to-year variation; climate is long-term trend.

Weather: Hailstorm in Florida; Heatwave in Alaska

Climate: "Florida is warm"; "Alaska is cold"

US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

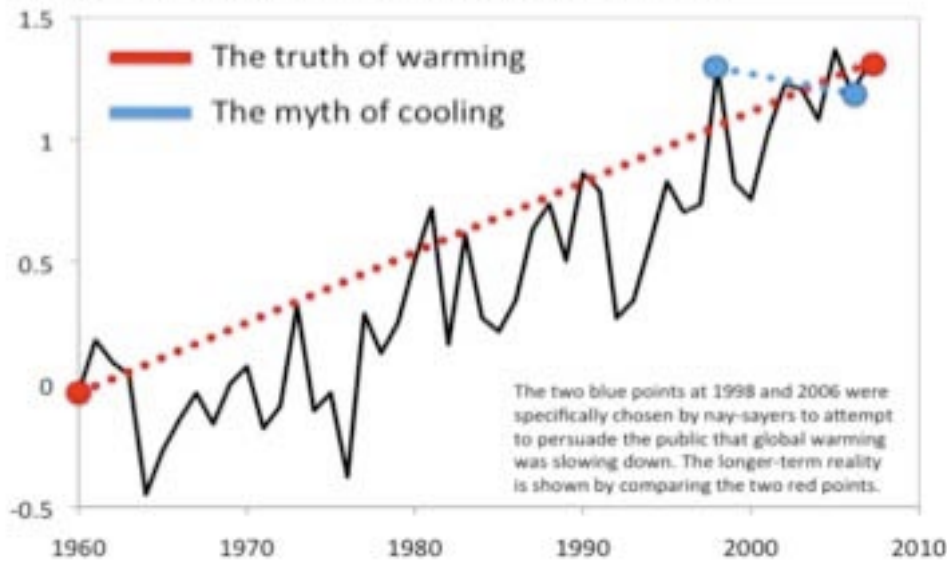
Weather is short-term; variable



Source: Katherine Hayhoe

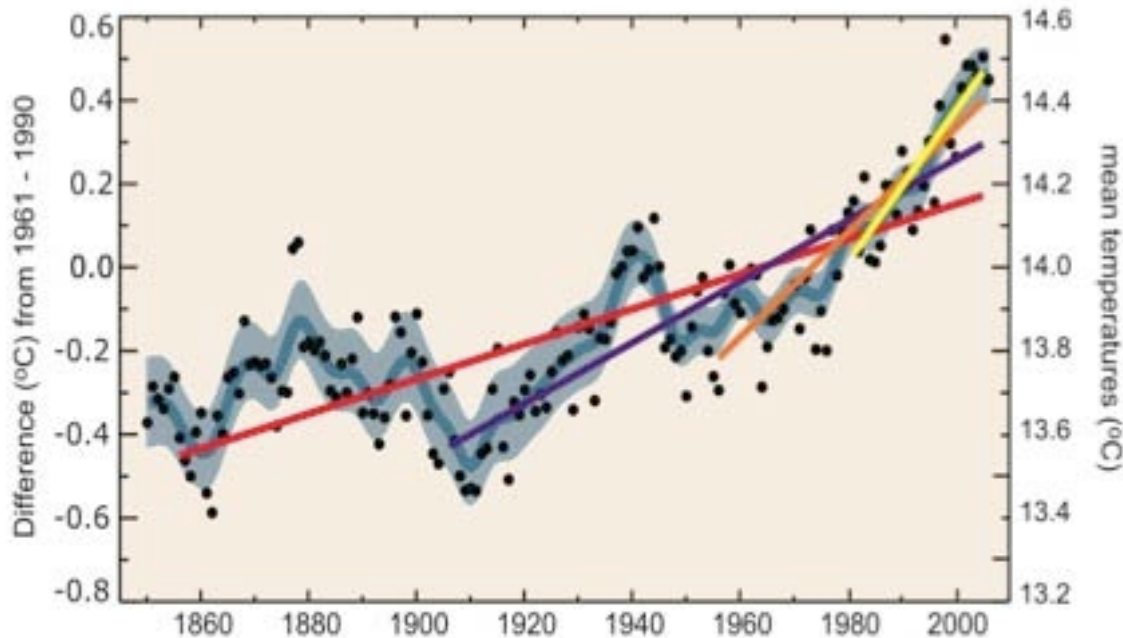
Climate is characterized by long-term, consistent trends

Temperature difference from 1950-1980 average ($^{\circ}\text{F}$)



Source: Katherine Hayhoe

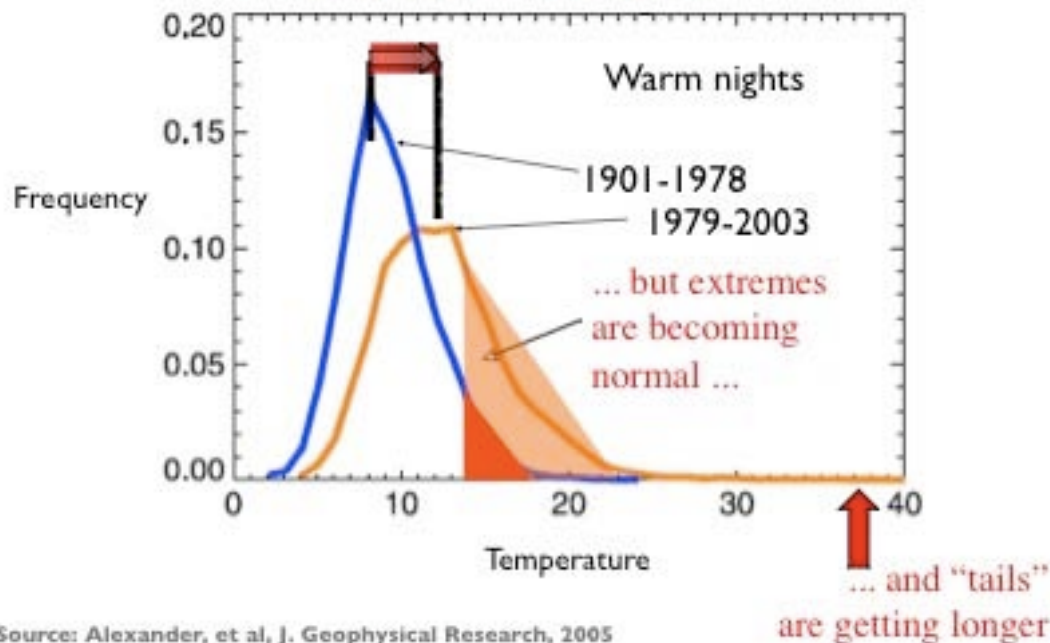
Climate Change is Accelerating



Source: Intergovernmental Panel on Climate Change, Fourth Assessment Report (2007)

Extremes Shift More Than Avg

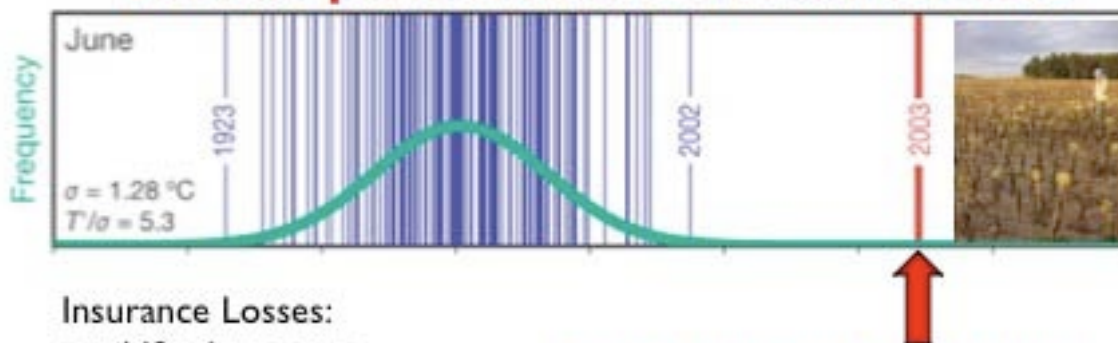
Small changes in averages...



Source: Alexander, et al, J. Geophysical Research, 2005

Rare Extremes Cause Most of the Damages & Insured Losses

The European heat wave of Summer 2003



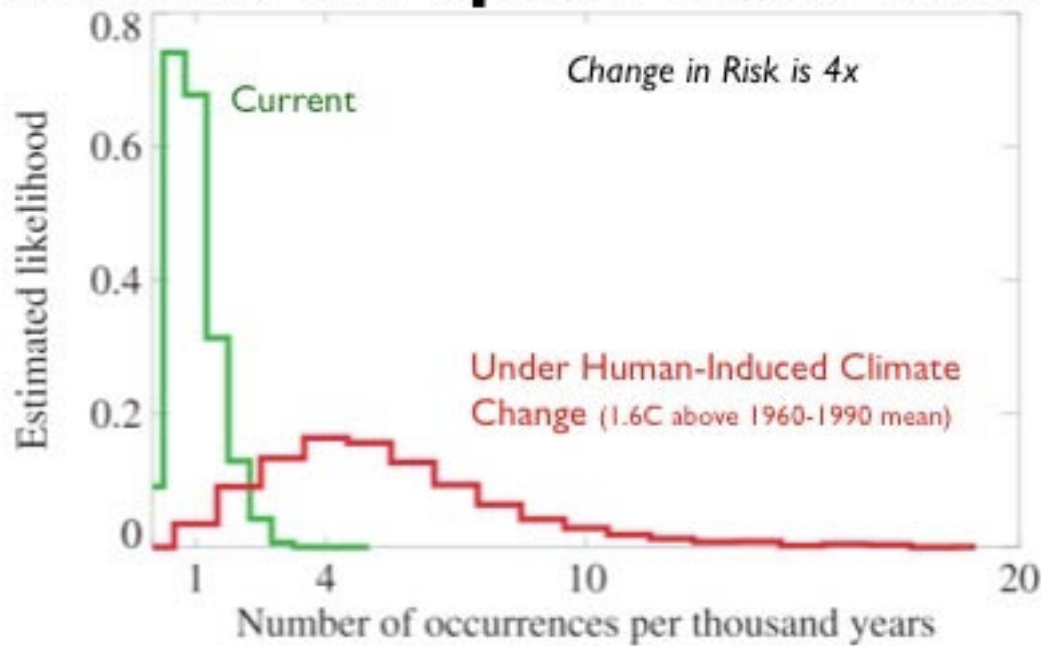
Insurance Losses:

- wildfire/property
- crop
- power sales
- health/mortality

Event was "six-sigmas" outside of norm.
16°F above average in France and Germany
was a 1-in-10,000 event to 1-in-46,000 event

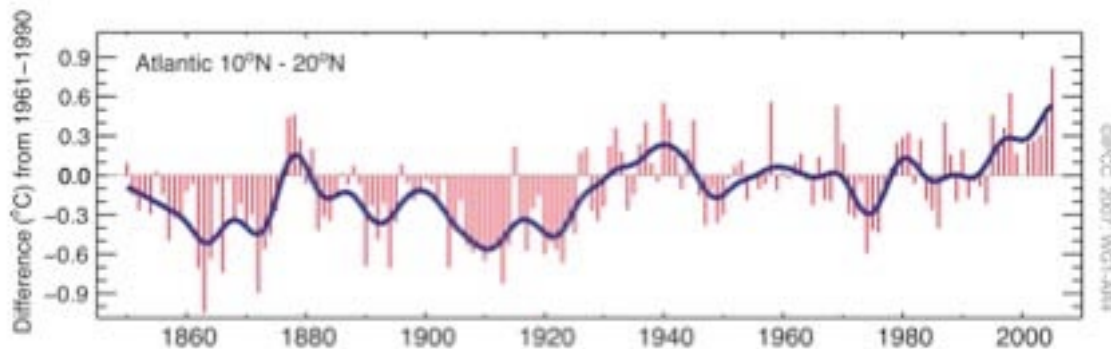
Source: Schar et al, Nature, v. 427, 2004.

Change in Frequency of Extreme European Heat Waves

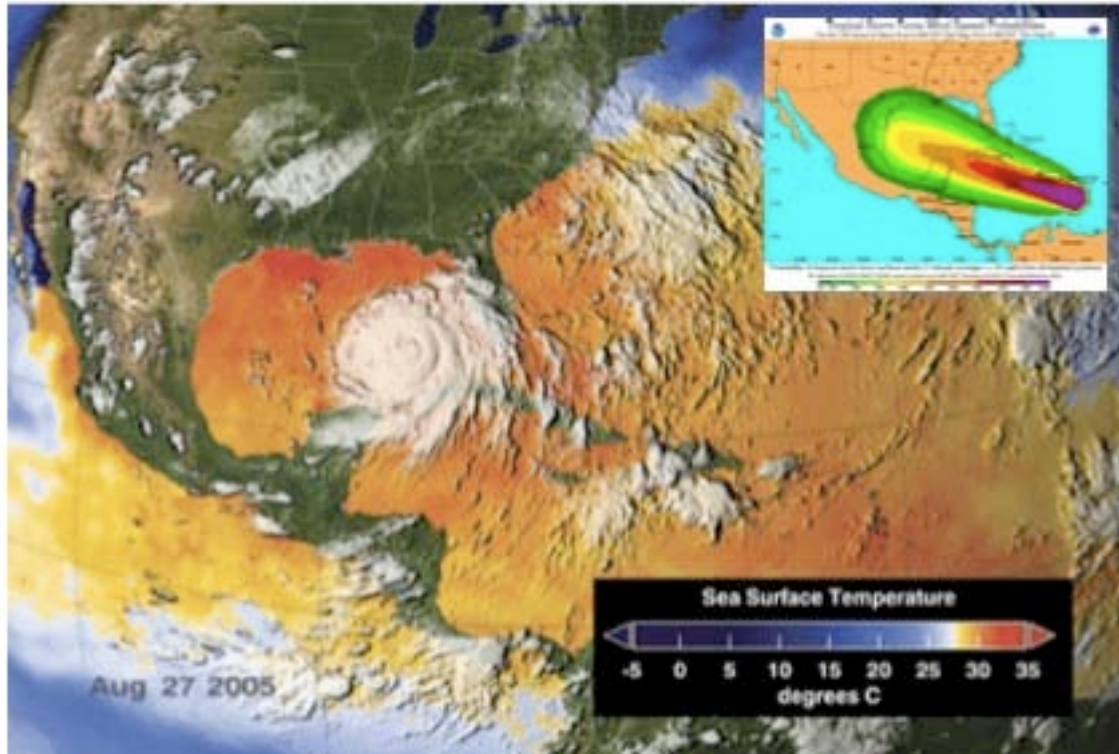


Source: IPCC AR4, Corresponds to 1.6°C change in mean

The Oceans are Warming, too...

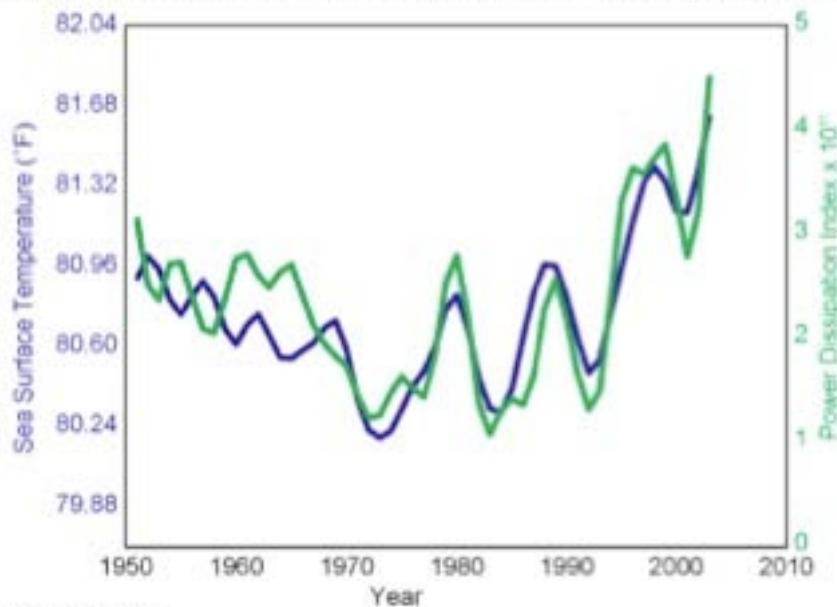


FINGERPRINTS ... Storms



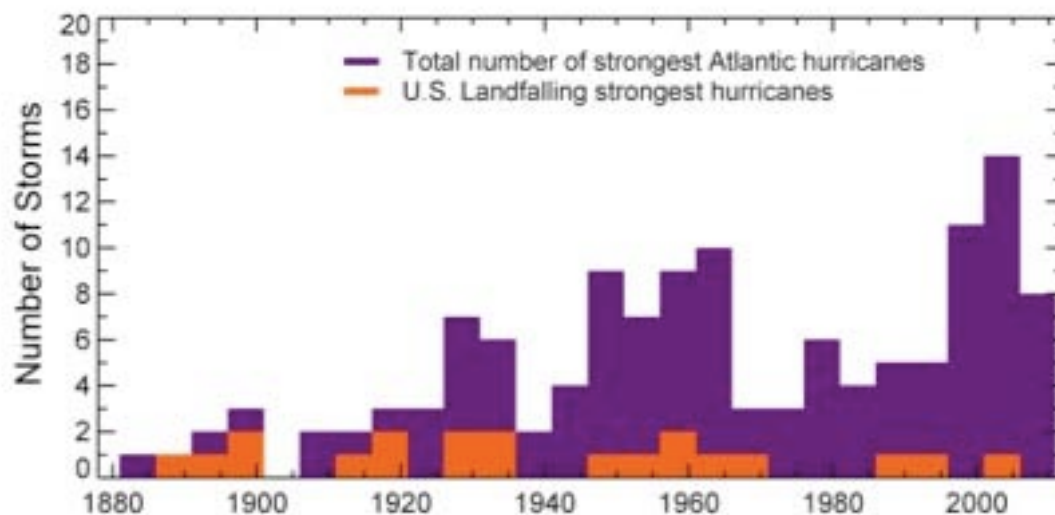
Observed Relationship between SST and Hurricane Power - N. Atlantic

Observed sea surface temperature (blue) and the Power Dissipation Index (green), which combines frequency, intensity and duration.



Atlantic Hurricanes

Strongest Hurricanes (Cat. 4 and 5)



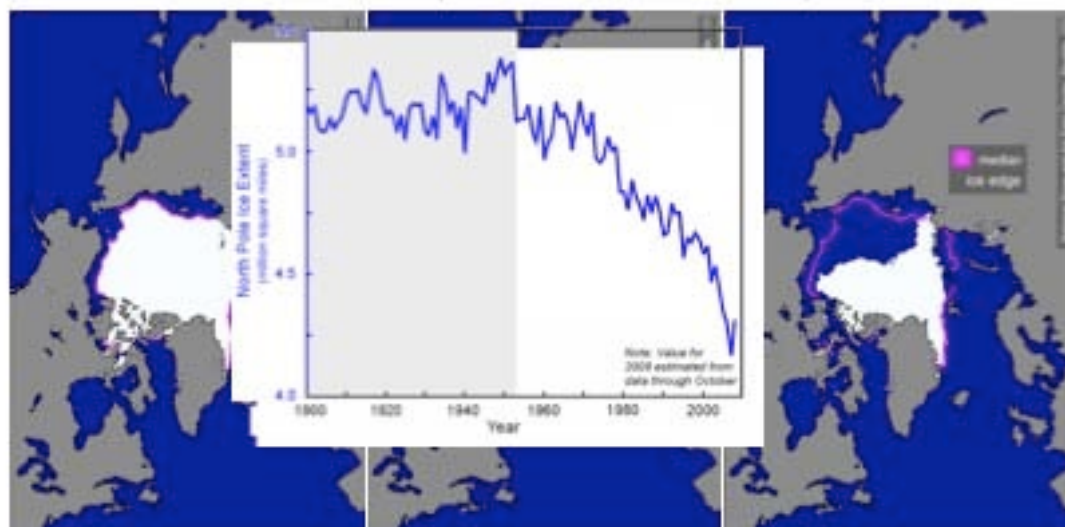
US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

FINGERPRINTS ... Polar ice

Median 1979-2000

September 21, 2005

September 16, 2007



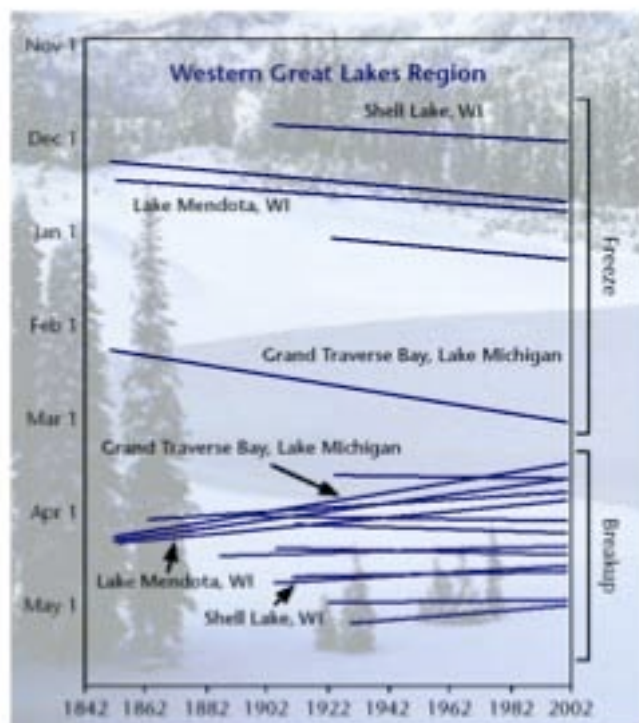
6.74 M square km

5.32 M square km

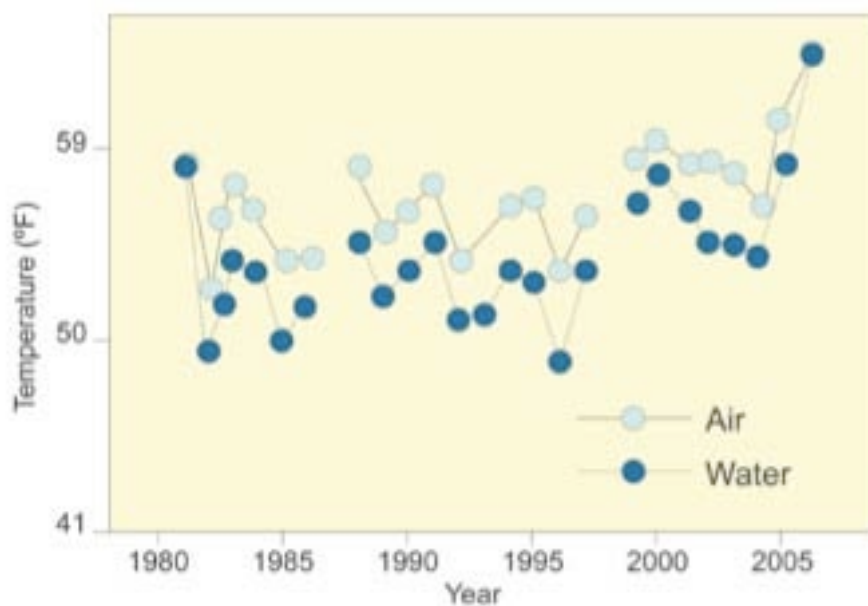
4.13 M square km

The difference between median minimum arctic ice coverage and the extent on Sept. 16, 2007 is equal to the area of Alaska and Texas combined (2.61 M sq. km or 1 M sq. miles). http://nsidc.org/news/press/2007_seaiceminimum/20070810_index.html

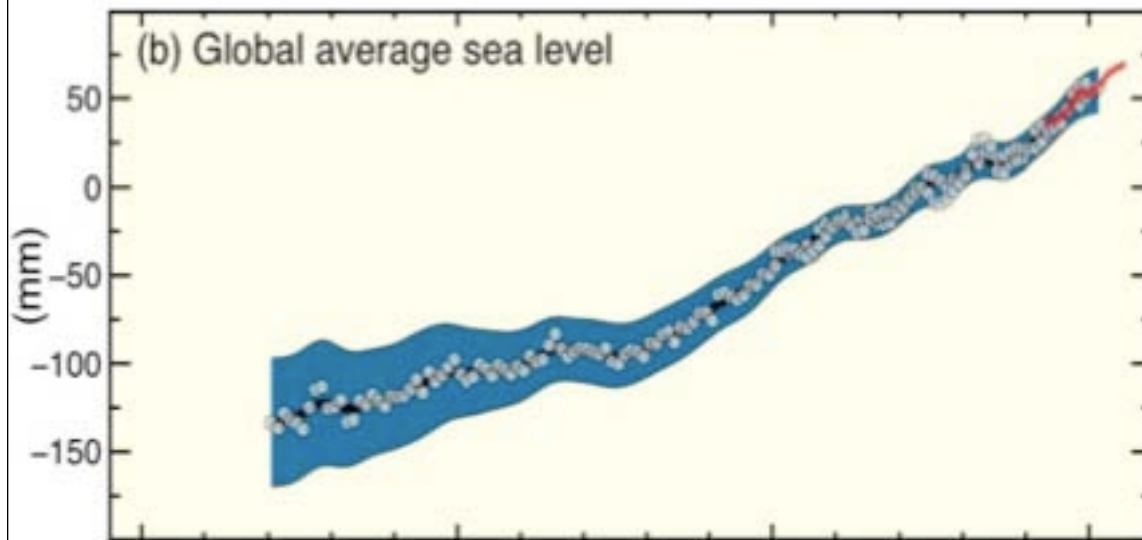
Annual period of Ice Cover on Lakes is Getting Shorter



Lake Superior Air and Water Temperatures Rising with Loss of Ice Cover, 1979-2006

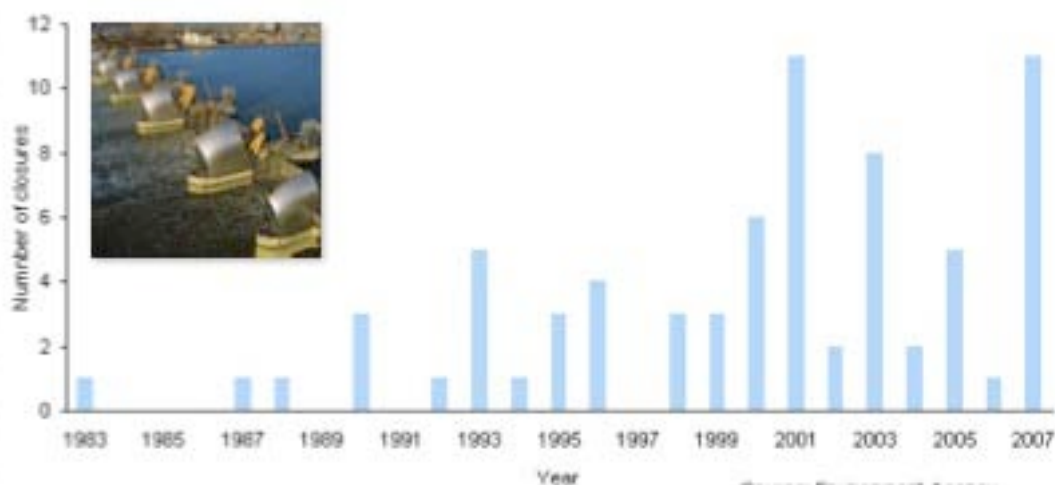


Sea-Level is Rising



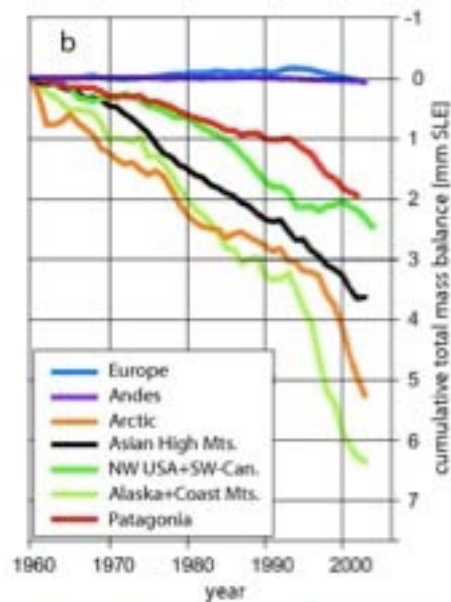
Source: Intergovernmental Panel on Climate Change, Fourth Assessment Report (2007)

Thames Barrier Closures against Tidal Surges: 1983-2007



Source: UK Environment Agency

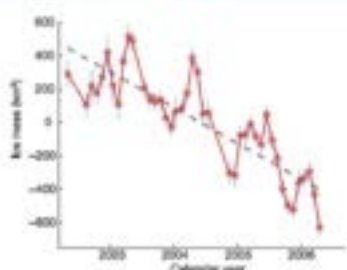
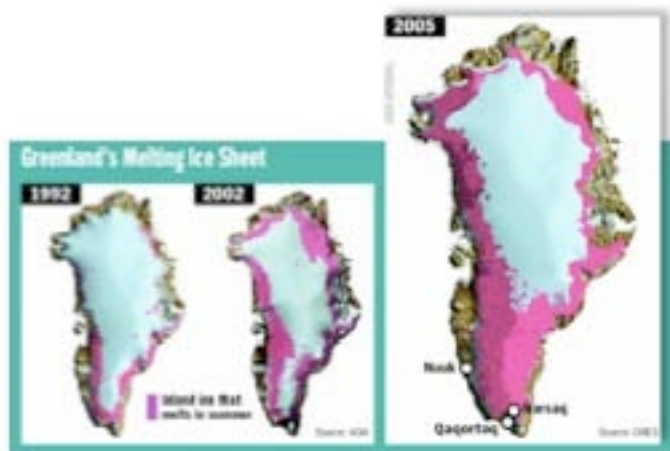
FINGERPRINTS ... Glaciers



Loss Accelerating since early 1990s

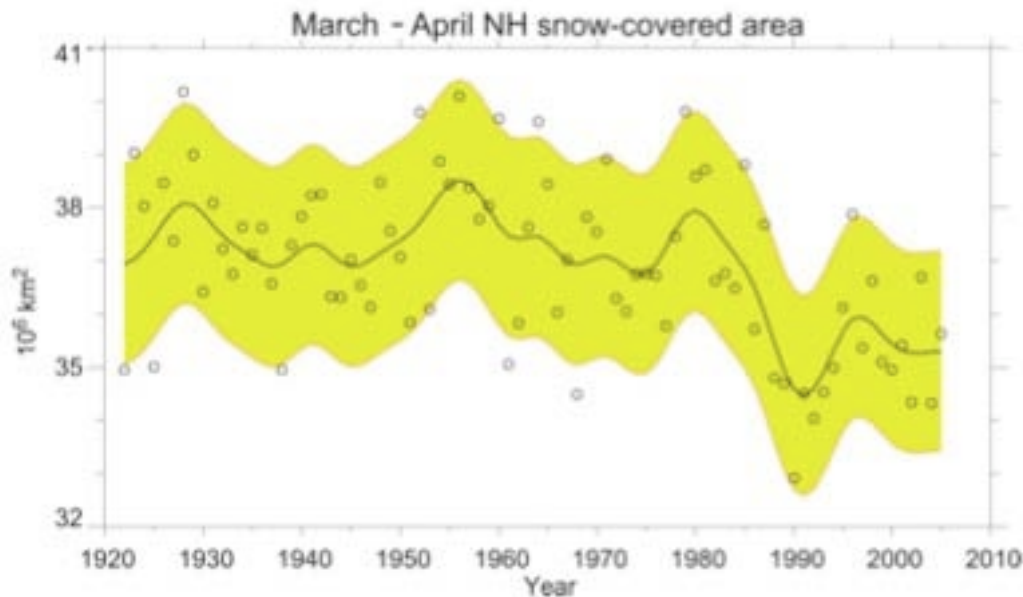
Source: IPCC 4th Assessment (2007)

FINGERPRINTS... Greenland



A 12-billion-gallon lake recently drained in 90 min (!) at the rate of Niagara Falls; sped up ice sheet

Snow Cover is Shrinking



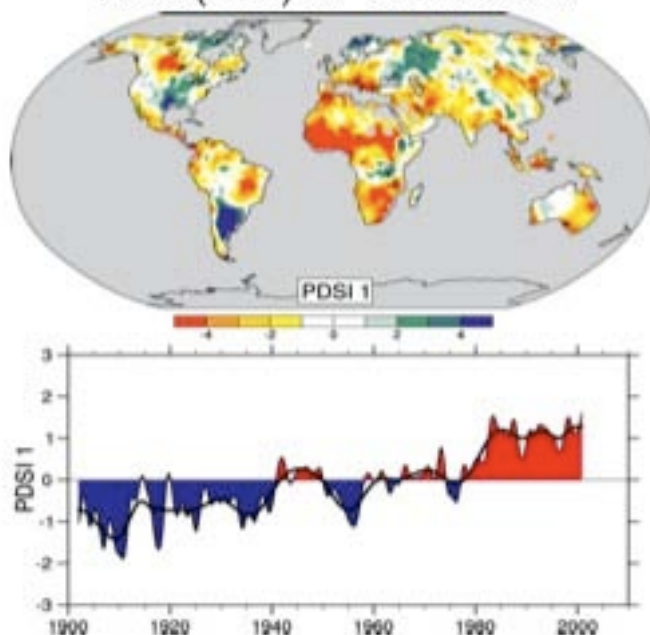
Source: Intergovernmental Panel on Climate Change, Fourth Assessment Report (2007)

FINGERPRINTS ... Drought

Change in Palmer Drought Severity Index (PDSI) for 1900 to 2002

Proportion of land area in extreme drought predicted to increase from 1-3% to 30% by 2090s.

Drought duration expected to increase 6-fold.

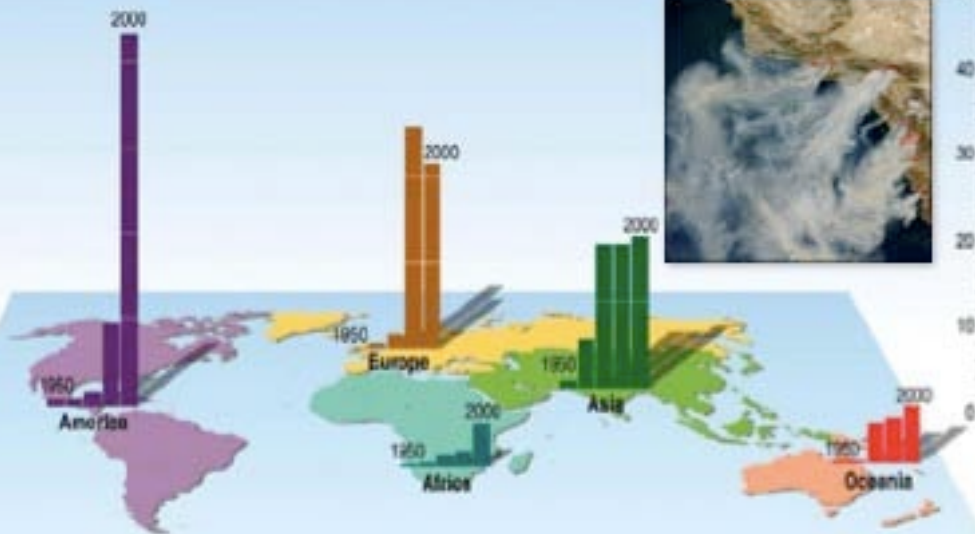


Source: IPCC 4th Assessment (2007)

FINGERPRINTS ... Wildfire

Major wildfires by decade, 1950-2000

Number of events
Data plotted by decade



Source: Millennium Ecosystem Assessment

The trend has been sharply upward everywhere; CO₂ feedback is significant

FINGERPRINTS ... Floods

Photos: Cedar Rapids "500-year" flood
(June 2008)

Major floods events per
decade, 1950-2000



Source: Millennium Ecosystem Assessment

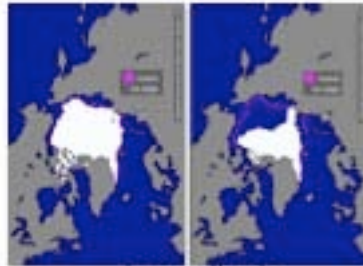
There's a consistent 50-year upward trend in every region except Oceania.

Positive Feedbacks

Canadian forests have become net carbon source (not sink)



temperature > beetles



ice > albedo



windstorm-downed trees > carbon



wildfire > carbon



ocean temperature and saturation > less CO₂ uptake



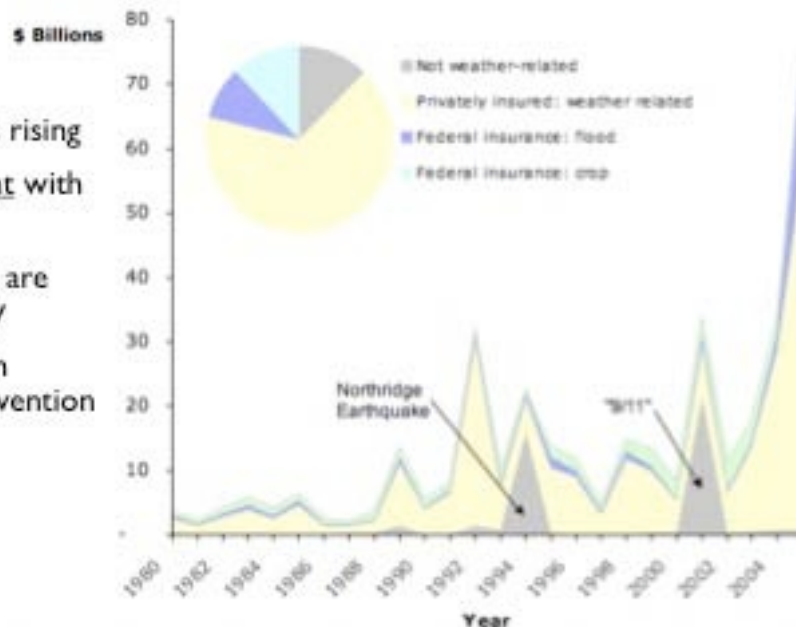
permafrost thaw > carbon

Net effect is accelerated warming

US CAT Losses: 1980-2005

but.....

- Number of events is rising
- Trends are consistent with observed change
- Non-weather losses are growing more slowly
- Trend would be even steeper without prevention efforts

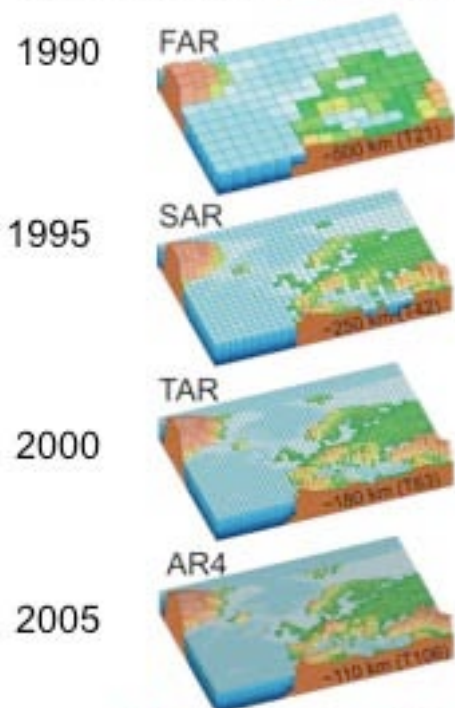


Source: U.S. Government Accountability Office, 2007

Excludes life/health losses



Climate Modeling Has Become Far More Precise



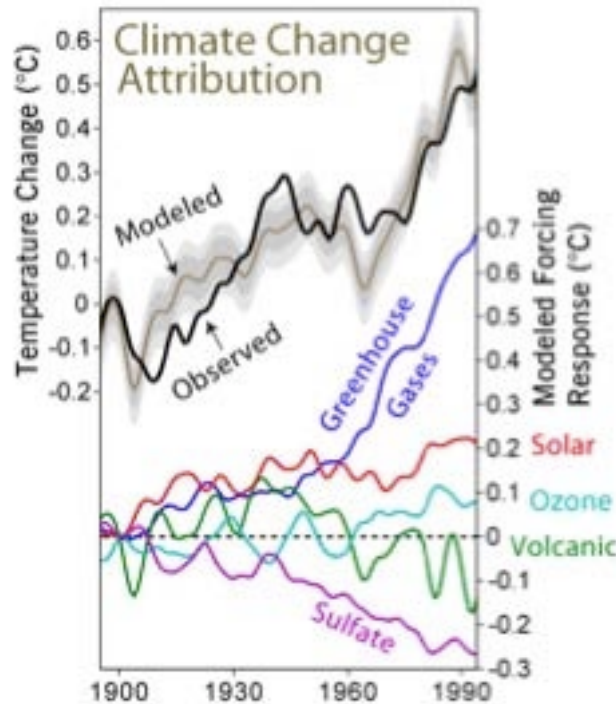
25x improved resolution!

The World in Global Climate Models



Source: Intergovernmental Panel on Climate Change, Fourth Assessment Report, WG I (2007)

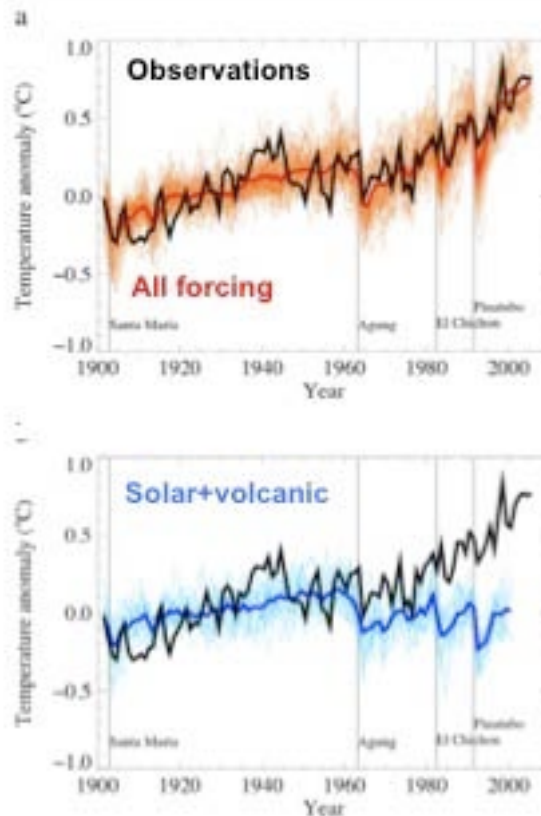
“Attribution”



Source: Katherine Hayhoe

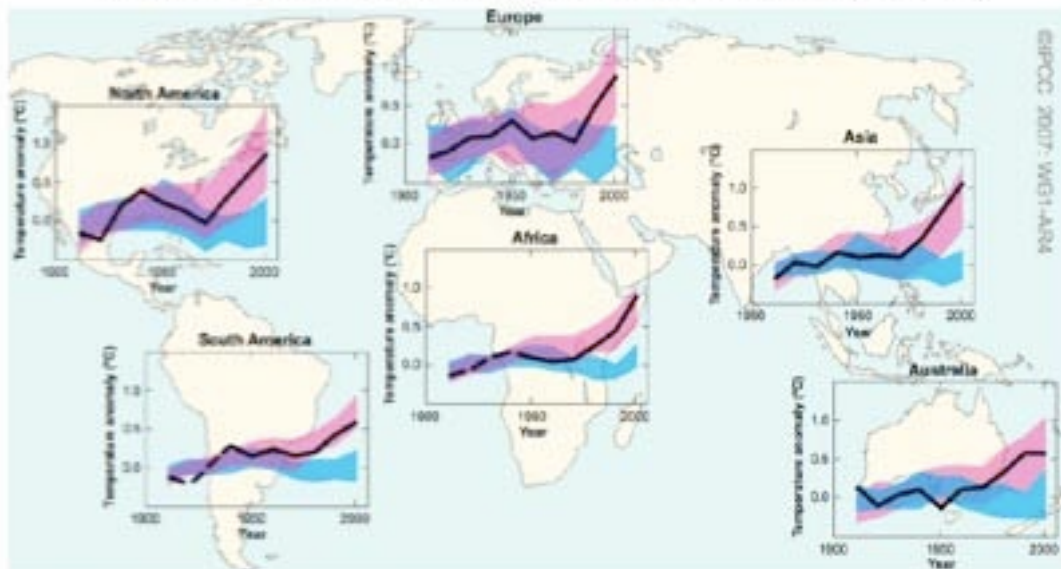
Attribution

Our models predict history very well, so we are confident in their ability to project future impacts



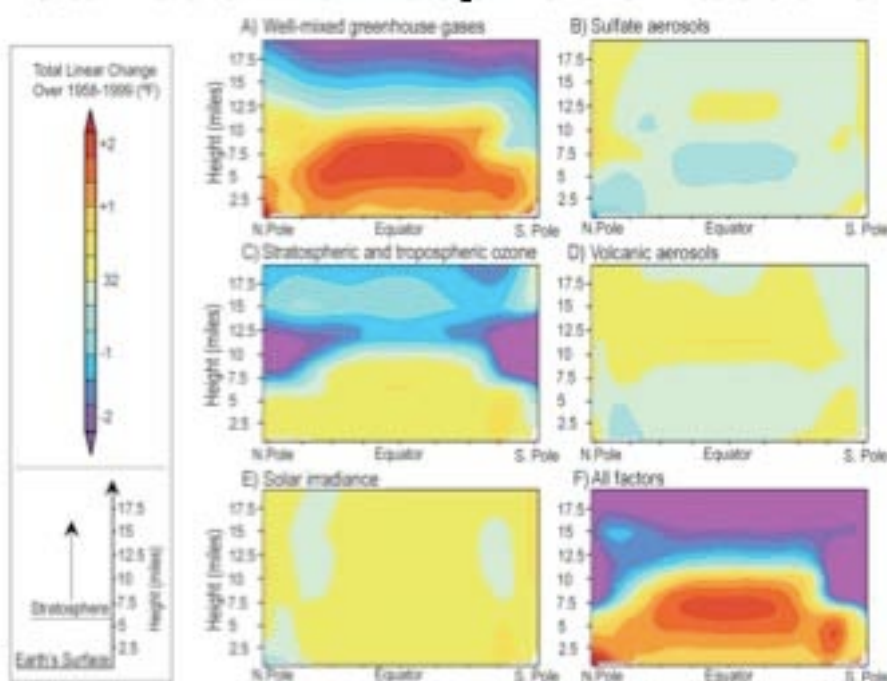
Source: IPCC 4th Assessment (2007)

Observations (black); models with human influences (pink); models without human influences (blue)



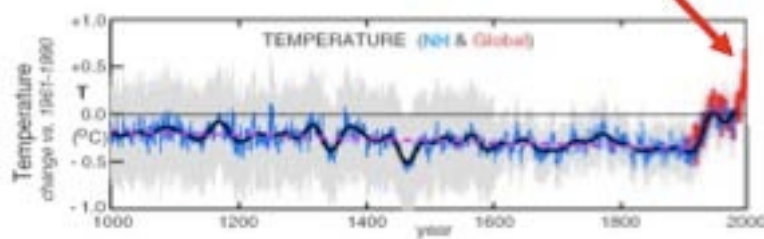
Source: Intergovernmental Panel on Climate Change, Fourth Assessment Report, WGI (2007)

Patterns of Temperature Change from Various Atmospheric Factors



Source: Intergovernmental Panel on Climate Change, Fourth Assessment Report, WGI (2007)

We're already
concerned about this



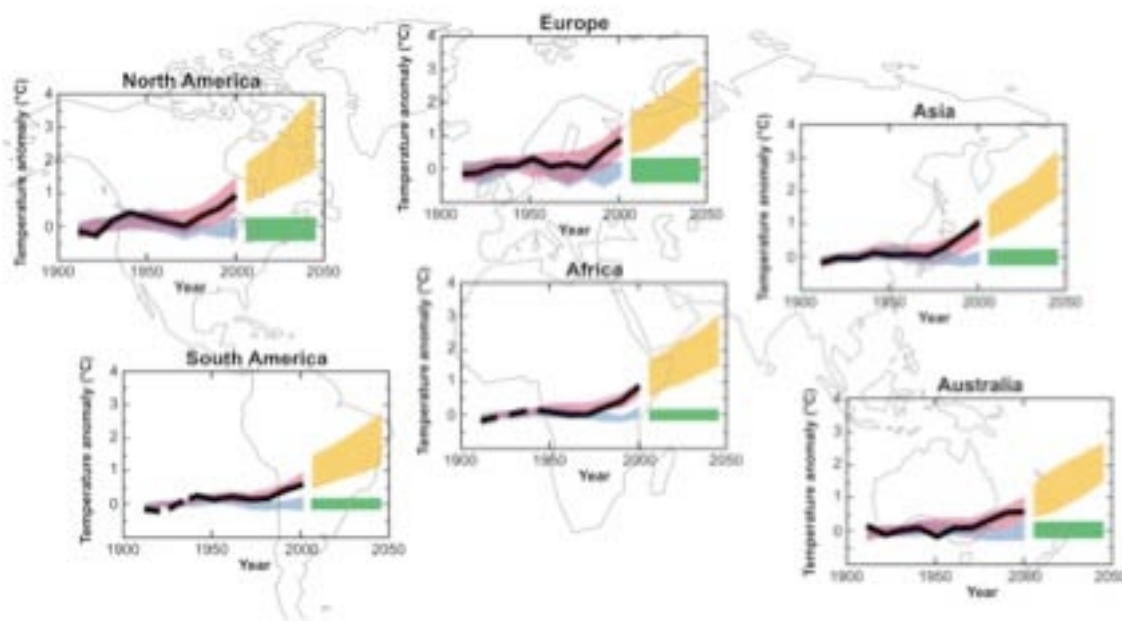
Source: Intergovernmental Panel on Climate Change, Fourth Assessment Report, WG I (2007)

But this is what's
coming next.



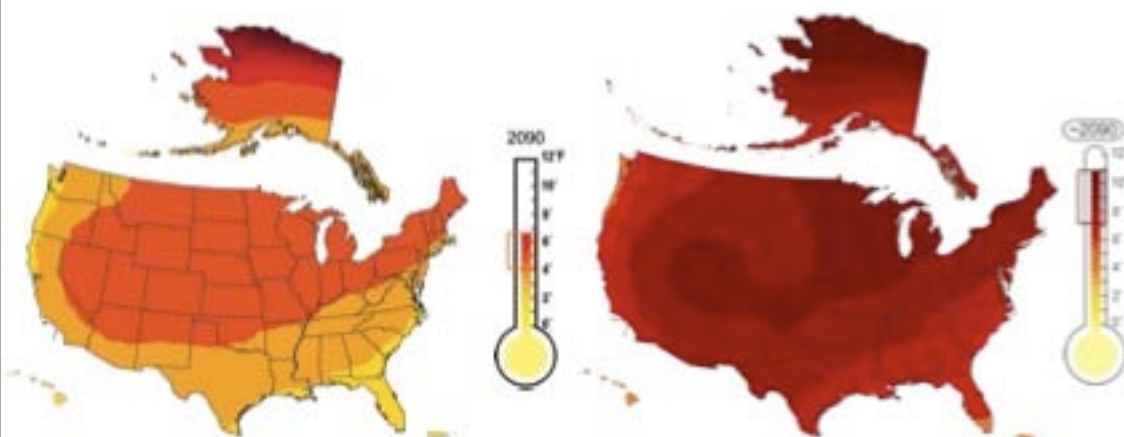
Source: Intergovernmental Panel on Climate Change, Fourth Assessment Report, WG I (2007)

Warming, everywhere



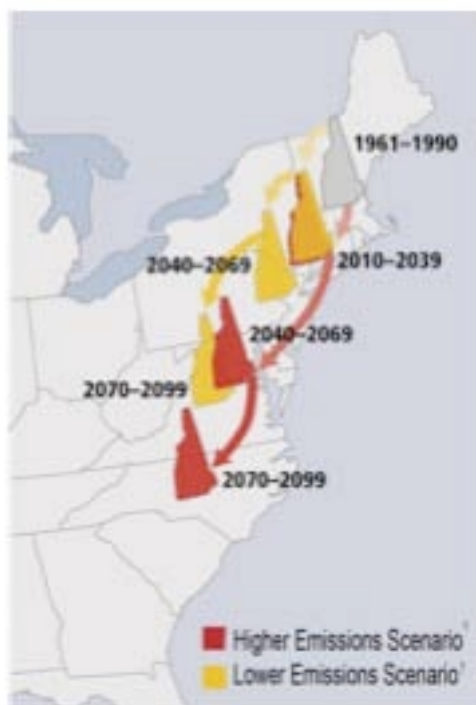
Source: Intergovernmental Panel on Climate Change, Fourth Assessment Report, WGI (2007)

Projected Temperature Change Under Low & High Emissions Scenarios[†] (2081-2099)



[†] Temperature differences from conditions as they existed from 1961 to 1979. Projected temperatures are based on 16 climate models. The brackets on the thermometers represent the likely range of model projections, though lower or higher outcomes are possible.

From New Hampshire to North Carolina

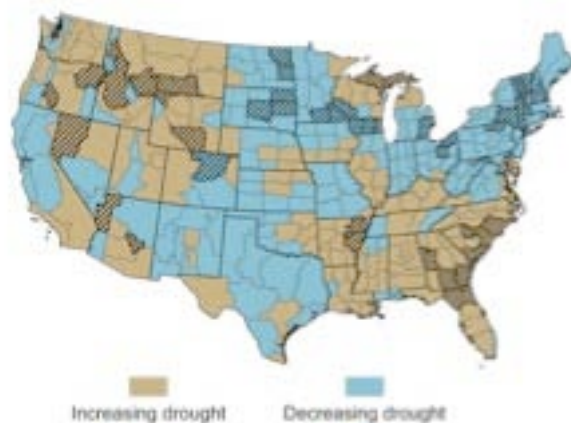


US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

Observed Drought Trends: 1958-2007

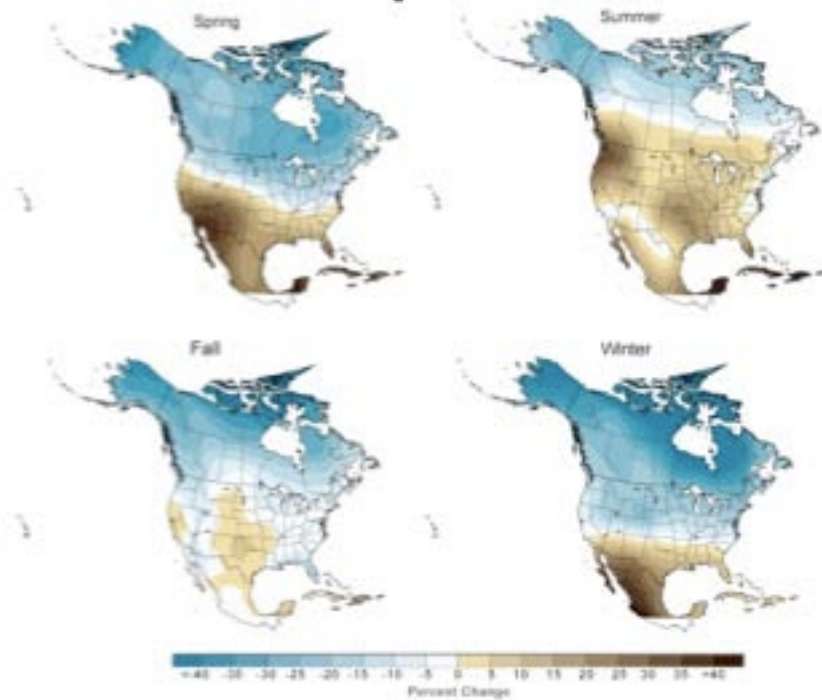


Potomac: 1997

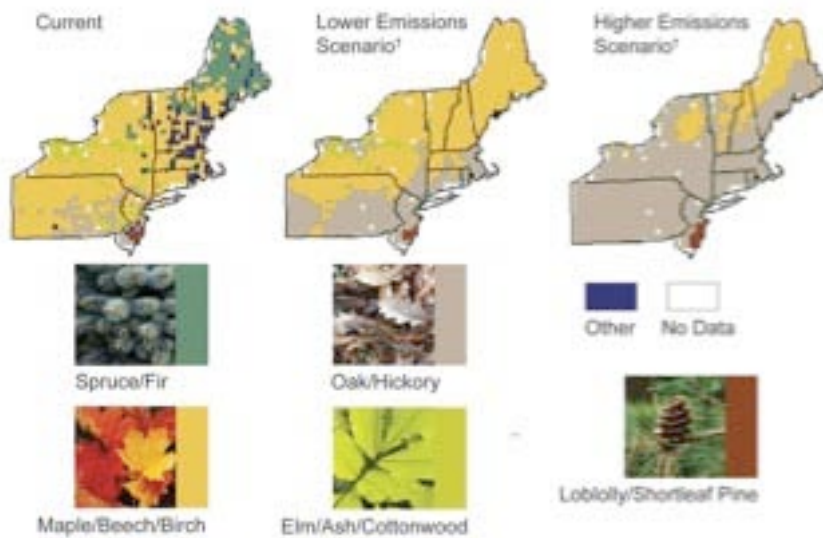


US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

Projected Change in N. American Precipitation



US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft



US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

Life/Health Dimensions

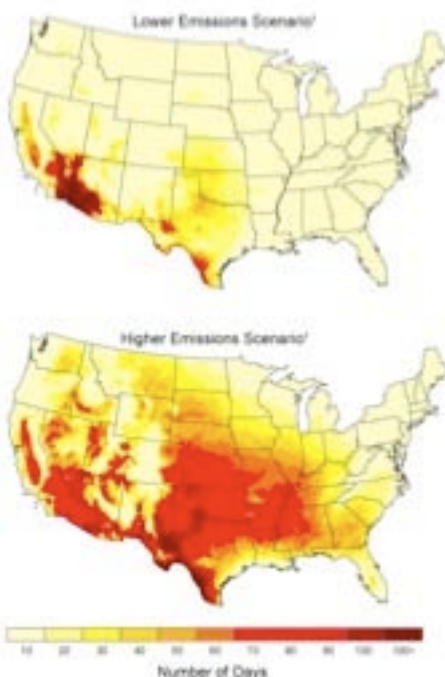
"The bottom line is that there are very real health risks associated with climate change."^{*}

- Centers for Disease Control and Prevention (CDC)
epidemiologist Howard Frumkin



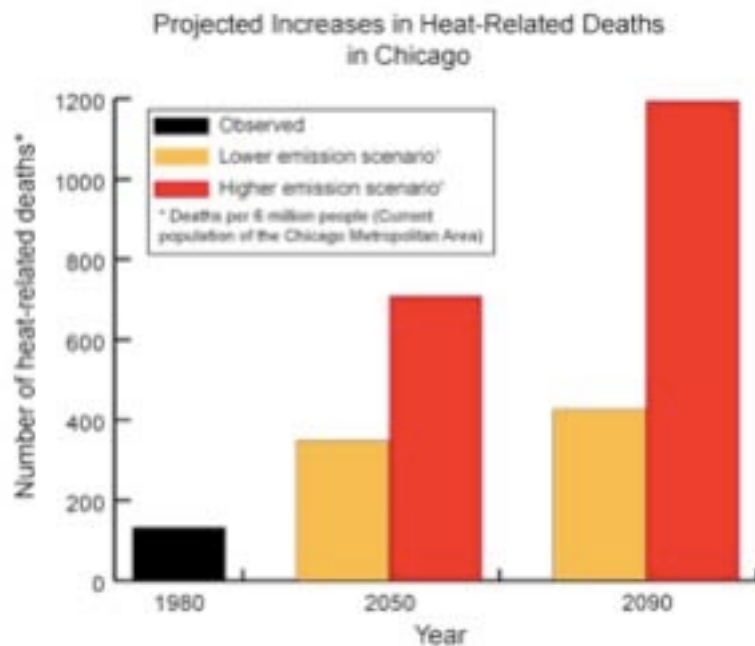
^{*}Eli Kintisch, *SCIENCE*, DOI: 10.1126/science.321.5888.477a July 25, 2008

Projected Increase in Number of Days with Heat Index over 100°F



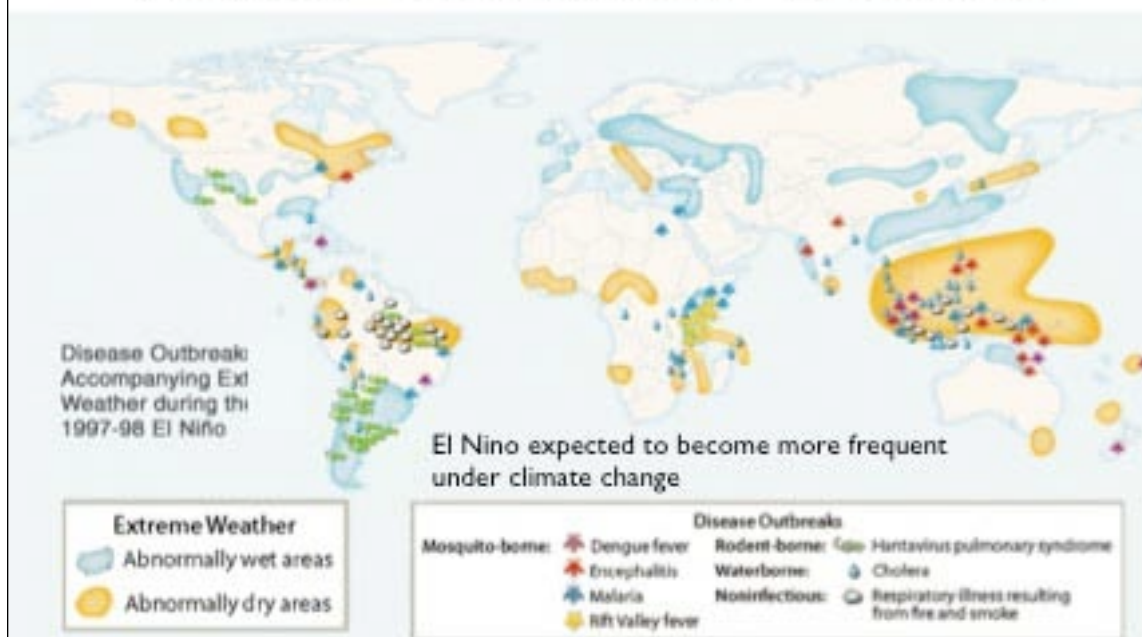
The number of days with a heat index (a measure that combines temperature and humidity to determine how hot it feels) over 100°F, compared to the 1960s and 1970s, is projected to increase strongly across the U.S. For example, the center of the nation is expected to experience 60-90 additional days per year in which the heat index is over 100°F.

Projected Increase in Heat-Related Deaths in Chicago



US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

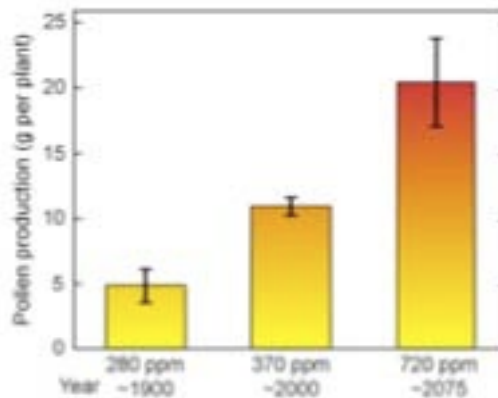
Correlation of Disease Clusters with the 1997-1998 El Nino Extremes



Source: P. Epstein, Harvard Medical School, Science

DIRECT Effects of CO₂

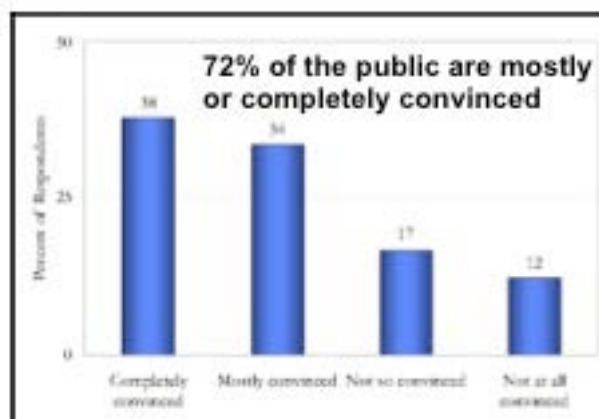
- Pollen increases “carbon fertilization”
- Oceans acidify > death of corals and many other organisms > fisheries impacts
- Herbicides become less effective



US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

Temperature of Public Opinion

- In 2007, twice as many people believed climate change is here than did in 2004
- But public opinion lags scientific certainty by a significant margin



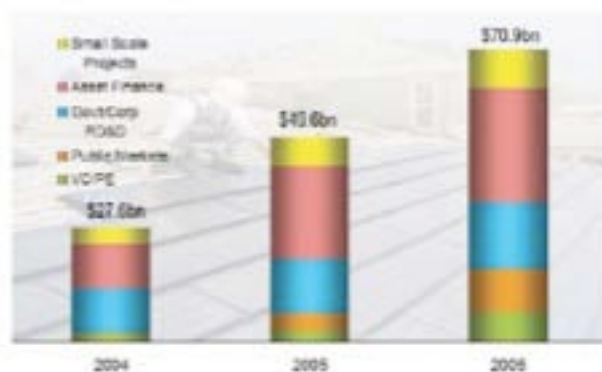
And.... diminishing differences by political party affiliation

Source: Yale-Gallup Poll (July 2007): <http://environment.yale.edu/news/Research/5317/americans-consider-global-warming-an-urgent-threat/>

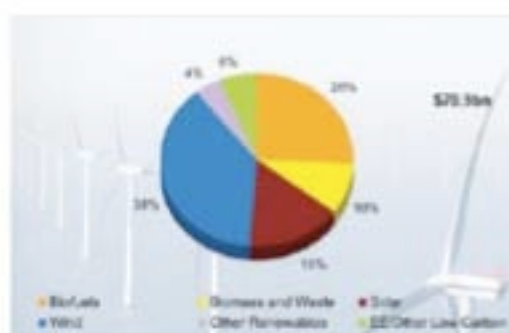
The Business Climate is Also Changing

Global Direct Investment in Sustainable Energy: 2004-2006

Investment by Type

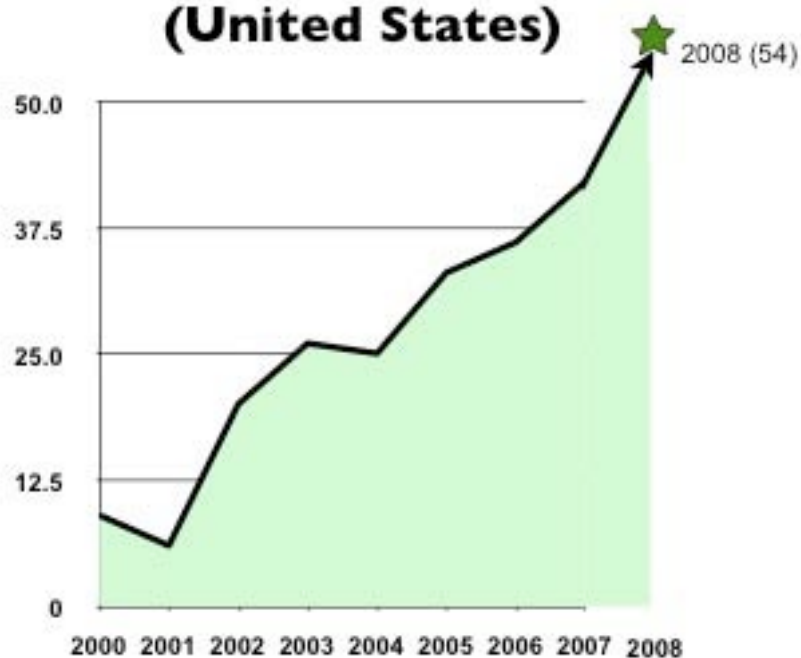


Investment by Technology



* Sylvie Lemmet, Division of Technology, Industry and Economics, UNEP.
 "Back to the Future: Investing in Clean Energy, Climate Action, p. 138 (2007)

Shareholder Climate Resolutions (United States)



Sources: 2000-2006 Data: ISS 2007; 2007 Data (as of 02.06.07): Ceres 2007 & 2008

Customers

“Most scientists believe that greenhouse gas emissions from human activities are influencing the earth’s climate. Duke Energy shares that view.”

“... Congress needs to establish a national, economy-wide greenhouse gas mandatory program as soon as possible.”

**Duke Energy (CEO Jim Rogers)
Corporate website as of March 2, 2008**

Emerging Risk: Liability

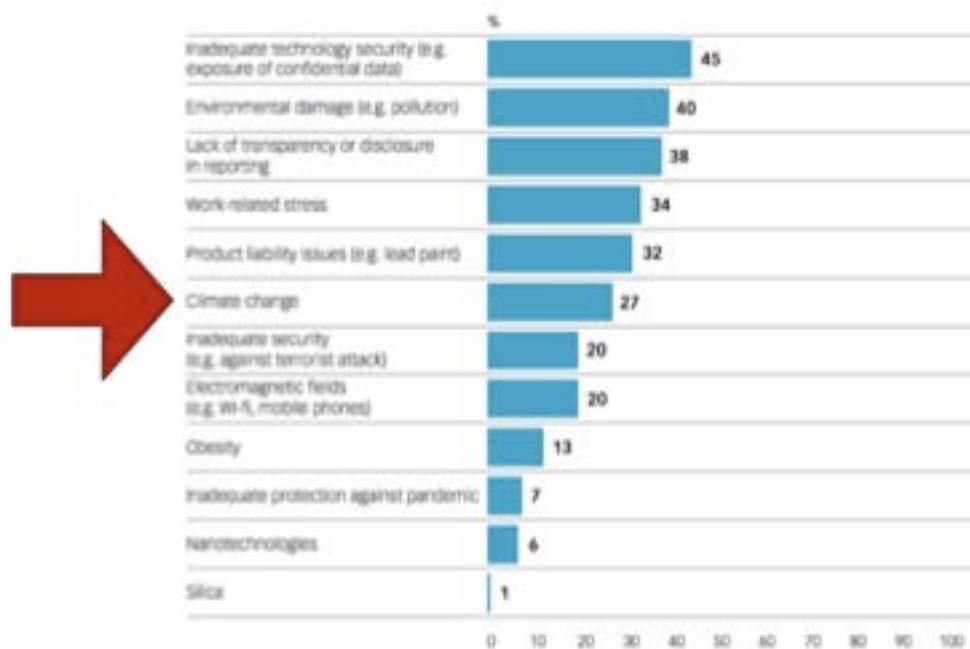


Oil spill following Hurricane Katrina - LIFE



> 100 climate law suits, and counting

Looking ahead five years, which of the following could give rise to a major new wave of liability claims?



Source: Lloyds of London, "Directors in the Dock: Is Business Facing a Liability Crisis?", Survey of 183 board-level corporate executives conducted by the Economist Intelligence Unit, 2008.

Climate Change is #1 Risk, According to >70 Insurance Industry Analysts (Ernst & Young Survey, March 2008)

1. **Climate change**
2. **Demographic shifts in core markets***
3. **Catastrophic events***
4. **Emerging markets***
5. **Regulatory intervention***
6. **Channel distribution**
7. **Integration of technology with operations & strategy**
8. **Securities markets***
9. **Legal risk***
10. **Geopolitical or macro-economic shocks***

* Also influenced by climate change



Changes in the Water Cycle

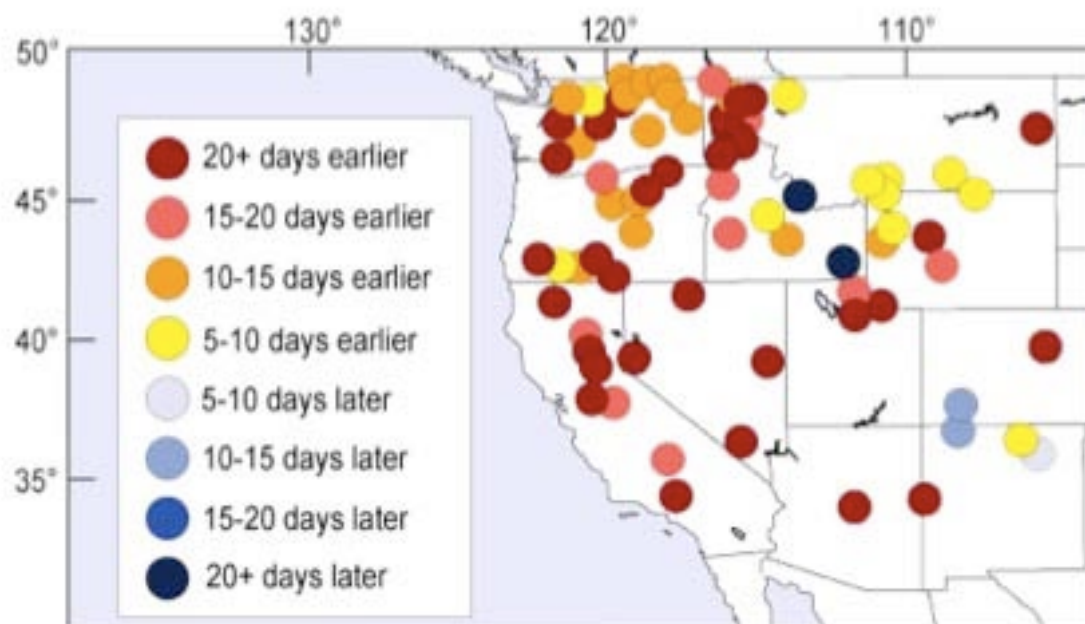


Changes in Snowfall Contributions to Wintertime Precipitation 1945-2005



US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

Spring Snowmelt Dates



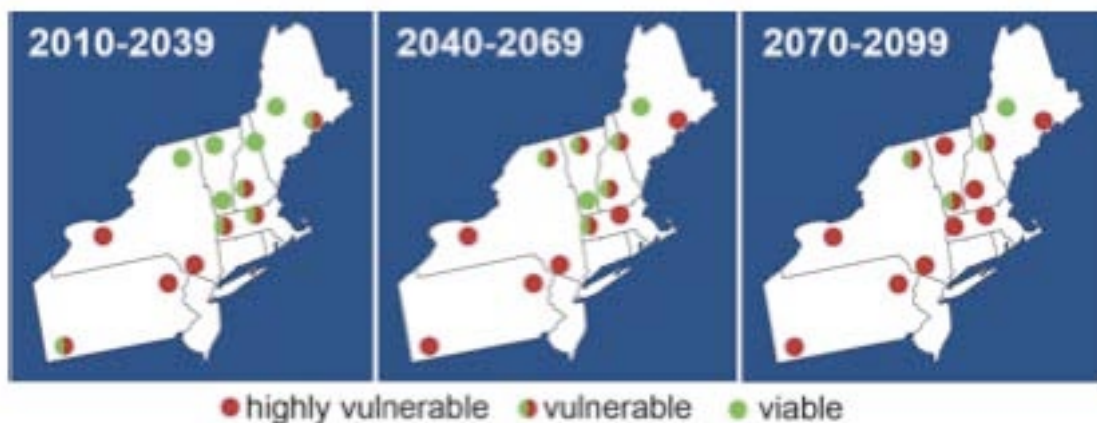
US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

Snow Cover in Northeast



US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

Fate of Ski Resorts?

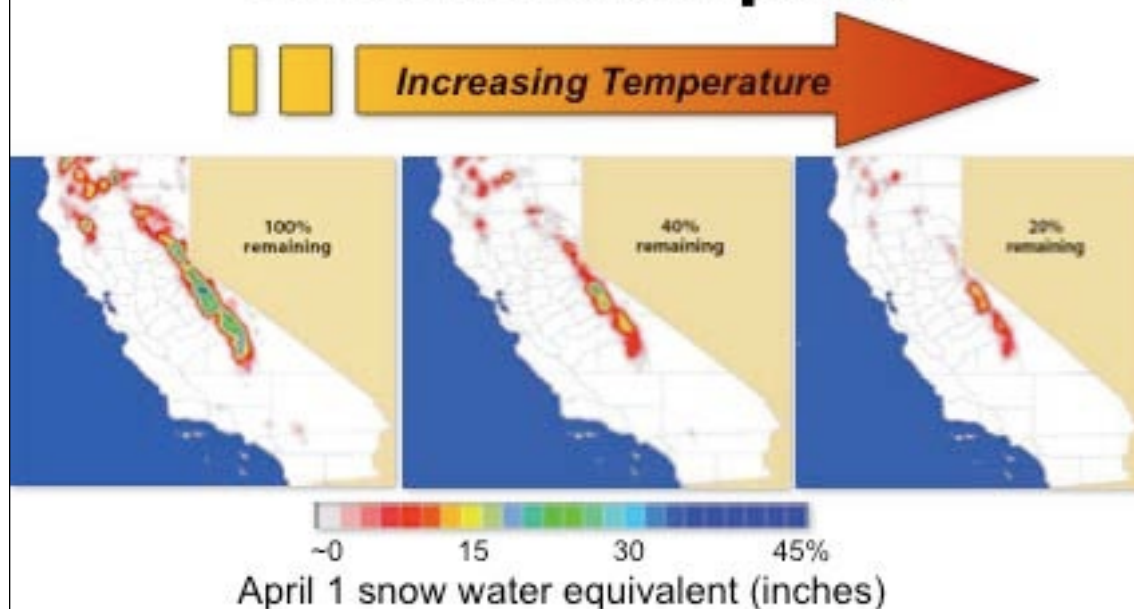


US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

Water Quality: California



Forecast Decrease in Sierra Nevada Snowpack



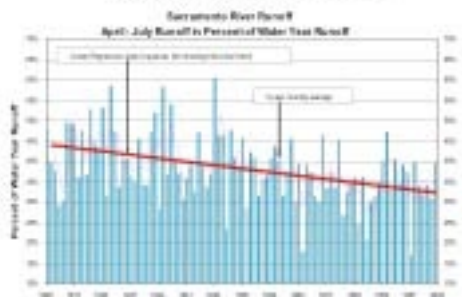
Source: Hayhoe et al. "Emissions pathways, climate change, and impacts on California", *PNAS* (2004)

Rising Salinity

Sea-level Rise



Reduced Runoff



Salt Water Intrusion (California Delta)



Example of salinity-rise episode during drought of 1992 (*Science* 2007)

Source: <http://baydeltaoffice.water.ca.gov/climatechange.cfm>

Sea-level Rise = 10 feet = half of Greenland melting



(Source:
Harvard University)

Sea-level Rise = 10 feet = half of Greenland melting



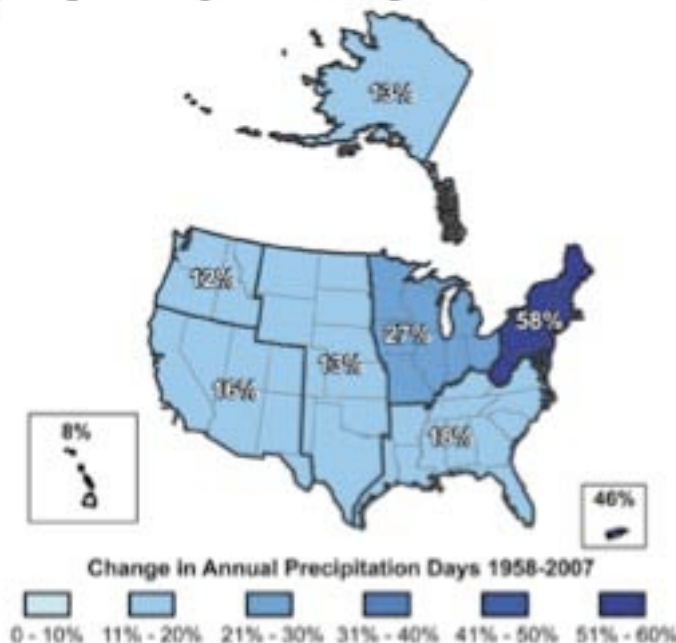
(Source:
Harvard University)

100-year flood zone becomes 10-year flood zone under CCSP high-emissions scenario and a 20-year flood zone under the low-emissions scenario by year 2100. Future 100-year flood will inundate much larger area.



US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

Increases in Very Heavy (top 1%) Precipitation Days,



US Climate Change Science Program, Unified Synthesis Product, January 2009 Public Review Draft

ABC News

Video Audio

News Home Just In Australia World Business Sport Entertainment Weather

Bushfire Emergency Full news coverage, video, audio and photos

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Firefighters work to protect water catchments

Posted 4 hours 7 minutes ago

Updated 3 hours 3 minutes ago

Fire crews are trying to stop bushfires spreading further into Melbourne's water catchments.

They have been working on backburning and strengthening control lines in the O'Shannassy, Armstrong and Upper Yarra catchments.

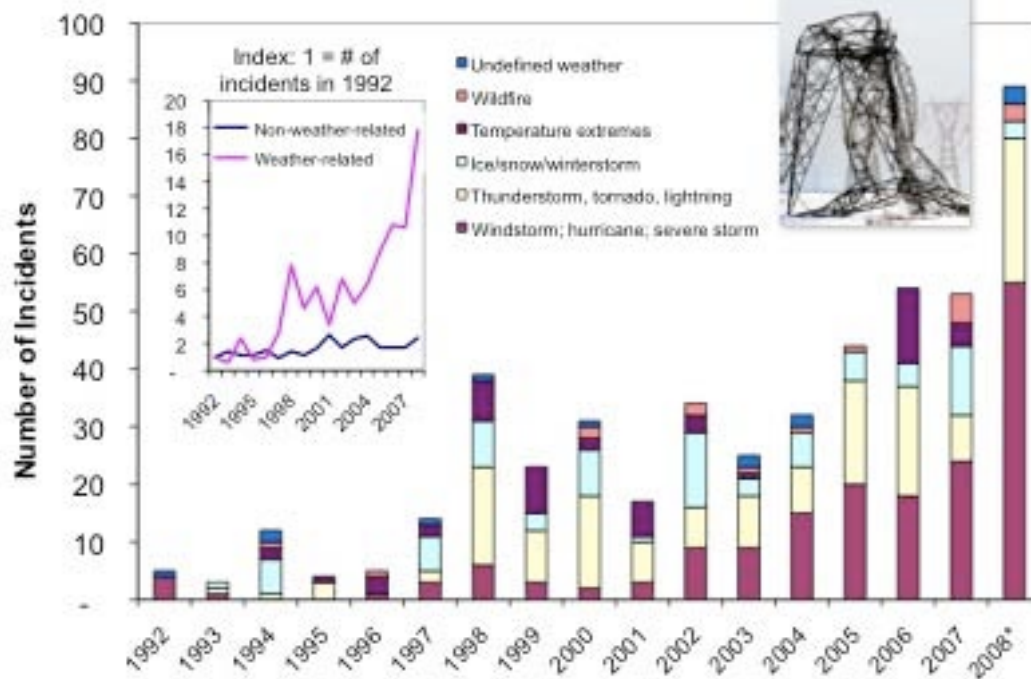
Country Fire Authority (CFA) spokesman David Harrison says crews want to stop the fire heading south.

"The main effort is in the construction of control lines in preparation for burning out



NSW rural firefighters look over maps of the Victorian bushfire situation as they wait to depart from Sydney Airport on Wednesday February 11 2009. (AAP: Tracey Neame)

Significant US Electric Grid Disturbances (1992-2008*) 484 Weather-Related Incidents



* 2008 data through August

Source: US Department of Energy

Energy and Water are ... Interdependent

Water for Energy

Energy and power production require water:

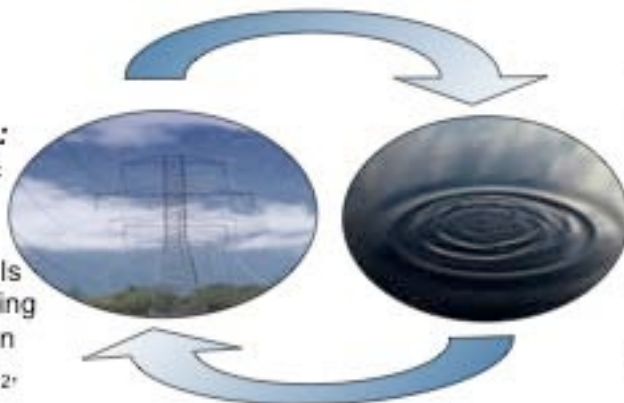
- Thermoelectric cooling
- Hydropower
- Energy minerals extraction/mining
- Fuel Production (fossil fuels, H₂, biofuels)
- Emission control

and

Energy for Water

Water production, processing, distribution, and end-use require energy:

- Pumping
- Conveyance and Transport
- Treatment
- Use conditioning
- Surface and Ground water

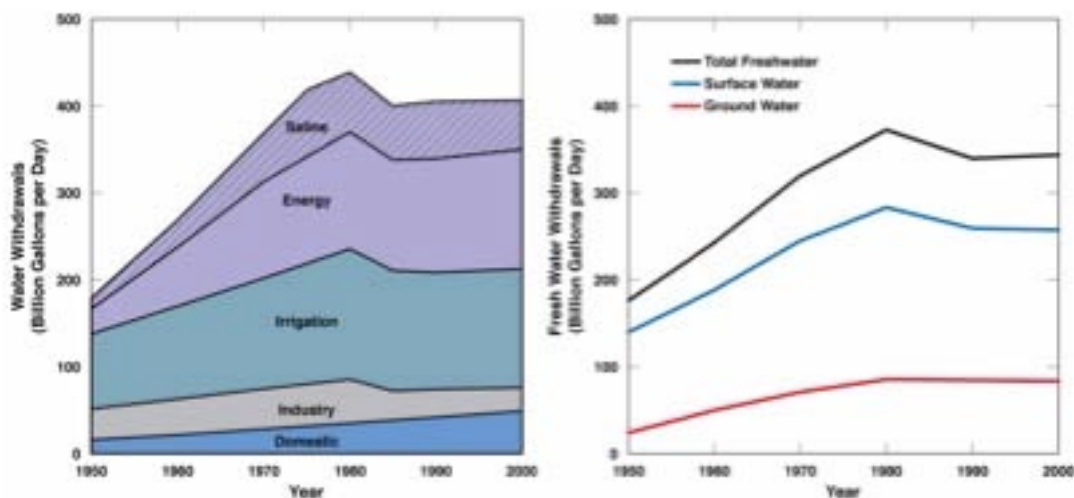


Water-Energy Connections



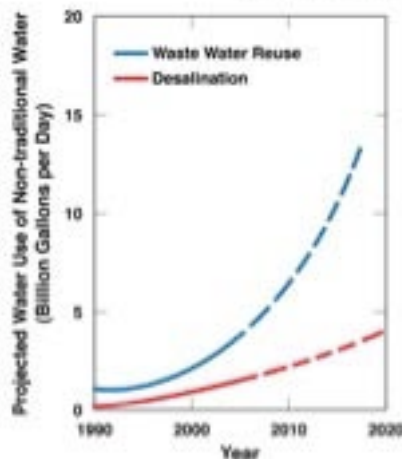
- Both under pressure
- Both impacted by climate
- \$4B/year of energy to handle/treat water
- Conserving has dual benefit of conserving energy and reducing greenhouse-gas emissions

Water Withdrawal Trends by Sector

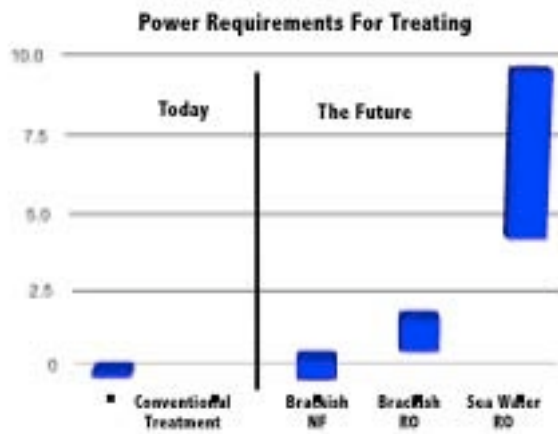


[USGS, 2004]

Growing Use of Non-traditional Water Resources



(From EPA 2004, Water Reuse 2007, Mickley 2003)



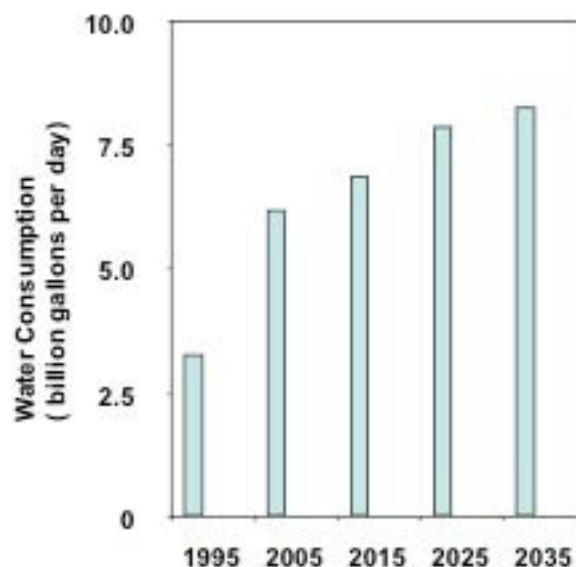
(Einfeld 2007)

- Desal growing at 10% per year, waste water reuse at 15% per year
- Reuse not accounted for in USGS assessments
- Non-traditional water use is energy intensive

Mike Hightower. "Energy and Water: Issues, Trends, and Challenges. Presentation to the Board on Earth Sciences and Resources, National Academy of Sciences, June 4, 2008

Water Demands for Future: Electric Power Development

- Water demands could almost triple from 1995 consumption for projected mix of plants and cooling
- Carbon emission requirements will increase water consumption by 1-2 Bgal/day



Source: NETL 2006

Mike Hightower. "Energy and Water: Issues, Trends, and Challenges. Presentation to the Board on Earth Sciences and Resources, National Academy of Sciences, June 4, 2008

2003 Heat Wave Impact on French Electric Power Generation

- Loss of 7 to 15% of nuclear generation capacity for 5 weeks
- Loss of 20% of hydro generation capacity
- Large-scale load shedding and shut off transmission to Italy
- Sharp increase of spot-market prices: 1000 to 1500 \$/MWh for most critical days



Normal conditions
in August

Bort-les-Orgues
Réservoir



August 27, 2003

Mike Hightower. "Energy and Water: Issues, Trends, and Challenges. Presentation to the Board on Earth Sciences and Resources, National Academy of Sciences, June 4, 2008

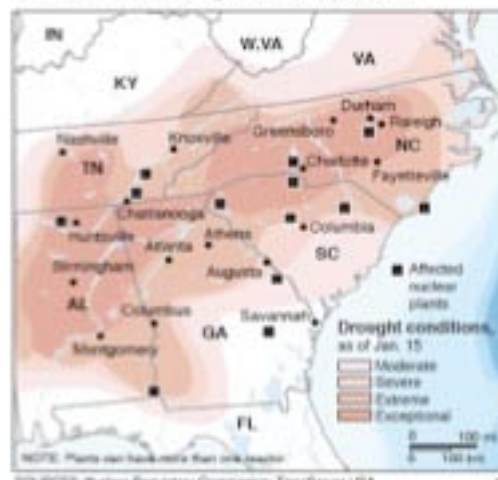
Closer to Home: Southeast U.S. Drought Impact on Nuclear Power Production

AP Associated Press
Jan. 23, 2008

“LAKE NORMAN, N.C. - Nuclear reactors across the Southeast could be forced to throttle back or temporarily shut down later this year because drought is drying up the rivers and lakes that supply power plants with the awesome amounts of cooling water they need to operate.”

Drought affecting nuclear plants

Twenty-four of the nation's 104 nuclear reactors are in areas experiencing the most severe levels of drought. Rivers and lakes supply power plants with the cooling water necessary to operate.



AP

Leading by Example

Loudoun Water's
carbon footprint?
~ 43 million
pounds or 21,000
tons CO₂
emissions per
year*

= 2,100 houses

= \$2.1M/year for
electricity



* Back-of-the-envelope estimate based on: \$2,100,000 divided by Dominion Virginia Power's average industrial electricity price (to get total kWh), times DVP's average carbon emissions of 1.223 pounds/kWh for the year 2005 per the US EPA's eGRID database.

Loudoun Water's Head Start

"We provide reliable water and waste-water services, while protecting the health and well being of our customers, the community and the **environment**."

- Loudoun Water Strategic Plan 2006 Update

"Anything that affects our customers affects us."

- Bringing Climate Change into the strategic planning process
- Following LEED principals in construction of Operations Complex of BRWRF and the ASF
- Exploring demand-side management
 - water re-use initiatives; "Brown is the new Green"; "Wise Water"
- Buying High and Selling Low

Next Steps

- Water/Energy/Carbon footprint analysis
 - identify best practices
 - end uses, benchmarking, potential
 - benchmarking
- Energy/carbon potential study
 - equipment
 - controls
 - system
- Look to utility for services, rebates, etc.
- Review investments; security of reserves
- Think about adaptations
- Measure, Evaluate, Feedback

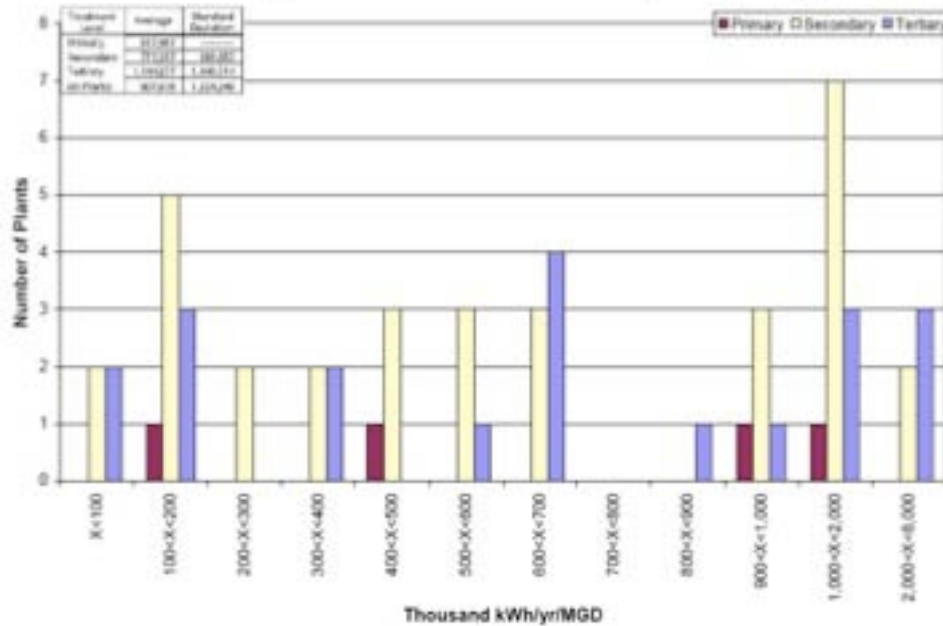
Reducing H₂O's Carbon Footprint (1 of 3)

- 10-30% efficiency potential for off-the-shelf, measures with payback times 1-3 years
- On average, supply = 60%; wastewater = 40% of total embodied energy
- Don't forget: facilities, motor pools, methane byproducts, etc.

See: "Energy Efficiency and Renewable Energy Technologies in Wastewater Management," Testimony of Richard E. Brown to the Subcommittee on Water Resources And Environment, House Committee on Transportation And Infrastructure, February 4, 2009, Lawrence Berkeley National Laboratory.

Huge Variance in Energy/MGD (56 Plants in PG&E Territory)

Electrical Usage Per Year Per Unit Flow Rate by Treatment Type



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Home > Buildings & Plants > Government > Water and Wastewater Industry Focus

Water and Wastewater Industry Focus

Improvement in water and wastewater energy performance represents a significant opportunity for many partners in EPA's **ENERGY STAR** program to gain financial and environmental benefits. To help them take advantage of this opportunity, EPA is building an energy efficiency Focus in the water and wastewater industries.

Drinking water and wastewater systems spend about \$4 billion a year on energy to pump, treat, deliver, collect, and clean water — with much of this cost borne by increasingly tight municipal budgets. The energy costs to run drinking water

[Water and Wastewater Industry Focus Fact Sheet](#) (55KB)

[EPA Press Release](#)

[List of Participants](#) (14KB)



Industrial Programs National Municipal Water and Wastewater Facility Initiative

Consortium For Energy Efficiency

[Home / Contact](#)

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- Water/Wastewater
- Motor Decisions
- Industrial Program Planning
- Transformers

Gas Programs

Multifamily

[Fact Sheet](#) [Initiative Description](#) [Water/wastewater links](#)
[Committee resources](#) [Regulatory updates](#)

The American Water Works Association Research Foundation (AWWRF) developed, tested and fielded a survey to water and wastewater facility supervisors, collecting important data about facility usage and energy consumption. The survey instrument developed for this project has been made available to CEE members. Click [here](#) for information about downloading and using these surveys.

Launched in December 2004, the National Municipal Water and Wastewater Facility Initiative will focus on promoting greater energy efficiency in publicly-held facilities, including those operated by municipalities, counties, water districts or authorities, and townships.

Reducing H₂O's Carbon Footprint (2 of 3)

- Digester biogas (combined heat and power)
- Effluent outfall in-flow hydro
- On-site renewables
- Purchase "Green Energy" off the grid
- Purchase/implement offsets elsewhere

Grid Inter-tied Atlantic County (NJ)
Utilities Authority wastewater
treatment plant



500kW solar



Saving
~\$400,000/year

Solar-Powered Mixing

Solar mixer, 10,000 gpm with 7 days of battery storage. Reduced odors claimed...



SolarBee Pump Systems

Reducing H₂O's Carbon Footprint (3 of 3)

- Customer-side water management
 - Efficient end-use devices
 - Re-use
 - Minimize evaporation
 - Many measures save both water and energy



Adaptation

Boston's Deer Island sewage treatment plant was designed and built 1.9 feet higher taking future sea-level rise into consideration

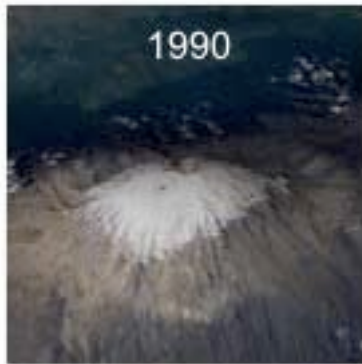


Planning Considerations

- Security of supply
- Water quality
- Infrastructure protection
- New drivers of demand
- Energy costs
- “Greening” of customer preferences
- Reputational risks
- Regulatory risks
- Insurance/Legal
- New partners? Utilities; carbon traders?

The past no longer a predictor of the future!

Tanzania: Drought >



“When the winds of change blow, some
build walls ... others build windmills.”

- Chinese Proverb



<http://insurance.lbl.gov>
emills@lbl.gov

“When the winds of change blow, some
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- Chinese Proverb

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Links

Climate Change & Water

- Intergovernmental Panel on Climate Change - <http://www.ipcc.ch>
- US Climate Change Science Program - <http://www.climatechange.gov/>
- Scientists deliberating climate change - <http://www.realclimate.org/>
- Analysis of "Climate Skeptic" arguments - How to Talk to a Climate Skeptic
- University of Maryland Center for Environmental Science - Climate change impacts on the Potomac
 - http://www.al.umces.edu/research/landscapeecology/pi_3.html

• Managing Water, Energy & Carbon

- Water-Energy Technology Team (WETT) at LBNL
 - <http://water-energy.lbl.gov/>
- Water and Wastewater Energy Best Practice Guidebook. Focus on Energy Partnership, 98 pages
- EnergyStar for Wastewater Plants and Drinking Water Systems
 - http://www.energystar.gov/index.cfm?c=government.wastewater_drinking_water
- Consortium for Energy Efficiency initiative on wastewater
 - <http://www.cee1.org/ind/mot-sys/www.php3>